EXAMINING PERVASIVE TECHNOLOGY PRACTICES IN SCHOOLS: A MENTAL MODELS APPROACH

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ABSTRACT

Studies of computers and education have failed to account for the relevance and importance of tacit assumptions and unquestioned expectations that underlie educational technology practices. A major premise of this dissertation is that it is these taken-for-granted interpretations of technology that most significantly influence how technology is used in the sphere of education. It is thus analytically useful to examine technology use in education by investigating the assumptions on which currently pervasive educational technology practices are built.

I employ the concept of "mental models" to study current educational technology practices. An examination of the literature revealed key elements of the prevailing mental model of technology in education, which I call the mental model of computers as information technology and multimedia machines. In this mental model, computer technology is viewed as a means to provide students and teachers with Internet connectivity and access to extensive, up-to-date information. The computer's multimedia authoring capacity can then be utilized to synthesize the wealth of information culled from Internet sources into presentations with integrated text, graphics, sound, and video. I investigated how this mental model organizes thinking about technology use and education within a large-scale initiative to implement one-to-one computing in public schools, the Maine Learning Technology Initiative (MLTI).

The MLTI study highlights the pervasive influence and inherent inertia of an entrenched mental model. When users of technology draw upon a well-established and widely-shared mental model to drive their actions around technology, they will likely develop the tendency to view the particular mental model as *the* way technology is supposed to be used. Their technology experience and pattern of use, guided by the existing mental model, in turn reinforce the community's established mental model of technology use, institutionalizing a set of technology practices and routines. An entrenched mental model can have pervasive influence in limiting individual and collective capacities to pursue possibilities outside of the established approach, or to recognize the need for such pursuit. This was observed during the first years of the MLTI, and is happening on a larger scale in the education system as more and more computers become available in classrooms.

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Now on the last day of the festival, Hoshana Rabbah, Jesus stood and cried out, "If anyone is thirsty, let him keep coming to me and drinking! Whoever puts his trust in me, as the Scripture says, rivers of living water will flow from his inmost being!" (John 7:37-38)

The past three years have been a constant struggle for me to finish this work. There were many difficult and discouraging days. May I never cease to thank God for family and friends who have been sources of God's living water, bringing joy, hope, and rest into my life: Amy and Kevin and their children, Andrew and Kaitlyn, Danielle and Kevin, Claudia and Luigi and baby Martina, Yong, Pan and Tracy, Eric and Michelle, Jen and Jason and baby Jack, Jamie and Lorri and baby Lily, Aya and Carter, Fletcher, Mike K., Criswell, Mike D. and Jane, Ryan and Melissa, Sarah, Derrick and the students at Bexley Hall, Art and Betty, Judy and David, Robin, Lourdes and Balz, Stuart, Ginger, Tina, Stacey, Mark, Kendra, Quentin and Ekua, Lu, Skye, Alaina, Melissa and Karen, RVL, George, Ruby, Roslyn, Ana, the Ungsukprasert family, Eileen and Alyssa, K. Busaba, Angie, Nina, Auntie Angeli and Uncle Robert, Pam, Joy and Oat, Auntie Jun, Nong Plai, Uncle Ya, J'Pearl and P'Tong and baby Nara, Donna and Mike H., Aunt Martha, Nana, Brandon and Juli, Bryan and Stephanie, and Tom and Janet Ridley.

I dedicate this thesis to my Dad Vatcharin, my Mom Sauvakon, my sister Vicky, to Grandma Malai and Grandma Somsuk, and to my husband, Brent Ridley.

I have spent the past seven years studying how we think children can be better educated through the use of technology. I had chosen to study education because I was already thinking about the children God may bless me with one day. The more I studied, the more I realize that what I want for my children and the children who are already in my life is this:

Hear, O Isra'el: The LORD is Our God, the LORD alone. Love the LORD your God with all your heart and with all your soul and with all your strength. These words, which I am commanding you today, are to be first in your own minds and hearts. Then you are to teach and impress them diligently upon the minds and hearts of your children. Talk about them when you sit at home and when you walk along the road, when you lie down and when you get up. (Deuteronomy 6:4-7)

"Teacher, which is the greatest commandment in the Torah?" Jesus replied: "Love the Lord your God with all your heart and with all your soul and with all your strength. This is the first and greatest commandment. And the second is like it: Love you neighbor as yourself." (Matthew 22:36-39)

May we learn to love God with all our heart, soul, and strength and to love our neighbor as ourselves. There is only need for this one thing.

CONTENTS

1 INTRODUCTION

1.1 The Increasing Computer Presence in Schools

Computers are playing an increasingly important role in American education. Many educators, policymakers, parents, and more recently the students themselves, have rallied for increased availability of computers in schools and for the use of computers in students' everyday education. Since the mid 1980s, many researchers (in university[1], government[2], and corporate[3] settings) have developed and pursued a research agenda that investigated the feasibility and desirability of giving students and teachers constant access to a personal machine.

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[1] See, for example,
Sheingold, K., Kane, J.H., and Endreweit, M.E. (1983) "Microcomputer Use in Schools: Developing a Research Agenda," *Harvard Educational Review*, 53, pp. 412-432;
Becker, H.J. (1991) "How Computers are Used in United States Schools: Basic Data from the 1989 I.E.A. Computers in Education Survey," *Journal of Educational Computing Research*, 7, pp. 385-406;
Becker, H.J., Ravitz, J.L., and Wong, Y.T. (1999) "Teacher and Teacher-Directed Student Use of Computers and Software. Teaching, Learning, and Computing: 1998 National Survey," Center for Research on Information Technology and Organizations, University of California, Irvine.
[2] See, for example,
U.S. Congress, Office of Technology Assessment (1988) *Power On! New Tools for Teaching and Learning*. Doc. no. OTA-SET-379. Washington, D.C.: U.S. Government Printing Office;
U.S. Congress, Office of Technology Assessment (1995) *Teachers and Technology: Making the Connection*. Doc. no. OTA-CHR-616. Washington, D.C.: U.S. Government Printing Office.
[3] See, for example,
Sivin-Kachala, J. (1998) *Report and the Effectiveness of Technology in Schools, 1990-1997*. Software Publisher's Association.

"Though not yet universally accessible ... a more pervasive and ubiquitous technology presence is permeating the learning environment."[4] Over the past decade and a half, monetary investment in procuring computers in American public schools has steadily increased. "This shift in educational spending"[5] means that "slightly more than half of every dollar" that schools spend on educational supplies goes to technology.[6] Between 1991 and 2001, schools spent approximately $55 billion on technology purchases.[7] Overall, "national spending on school technology has increased"[8] and "the classroom has become an increasingly technological place."[9] Computers are now widely used by students and teachers in day-to-day classroom activities.

1.2 Organizations and Technology-Enabled Transformation

"Computers have transformed work," wrote T. Michael Nevens, a director at McKinsey's Silicon Valley office, "They could also transform education."[10] Citing research conducted annually by the CEO Forum on Education and Technology, "a partnership between leaders in business and education,"[11] of which McKinsey is a founding board member, Nevens highlighted the

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[4] "Trends Report 2001," Software and Information Industry Association (SIIA). <http://www.trendsreport.net>

[5] Oppenheimer, T. (2003) *The Flickering Mind: The False Promise of Technology in the Classroom and How Learning Can Be Saved* (p. xvii). New York: Random House.

[6] "The Complete K-12 Report: Market Facts & Segment Analysis, 2002," Education Market Research. As cited in Oppenheimer, T. (2003) *The Flickering Mind: The False Promise of Technology in the Classroom and How Learning Can Be Saved* (p. xvi). New York: Random House.

[7] "Technology Purchasing Forecast 2001-2002," Quality Education Data, Inc.

[8] Oppenheimer, T. (2003) *The Flickering Mind: The False Promise of Technology in the Classroom and How Learning Can Be Saved* (p. 196). New York: Random House.

[9] Ibid., p. *xvii*.

[10] Nevens, T.M. (2001) "Fast Lines at Digital High" (p. 167), *McKinsey Quarterly*. Fall 2001, pp. 167-177.

[11] Ibid., p. 168.

importance and growing impact of technology in education. He concluded with the following remarks:

> Digital technology is transforming the world of work. To produce the knowledge workers of tomorrow, and to maximize the ability of children to learn, it must also be allowed to transform the world of education.[12]

A significant portion of the voices advocating for increased investment in technology for schools has come from the business sector. While it is generally believed that technology is transforming the world of work, as it is doing in the world of education, it is also widely accepted that limitations on organizations' ability to capture the full potential of technology continue to persist and need to be studied.[13]

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[12] Nevens, T.M. (2001) "Fast Lines at Digital High" (p. 177), *McKinsey Quarterly*. Fall 2001, pp. 167-177.

[13] See, for example,
Solow, R. (1987) *New York Times Review*, July 12, 1987;
Brynjolfsson, E. (1993) "The Productivity Paradox of Information Technology: Review and Assessment," *Communications of the ACM*, vol. 37, no. 12;
Landauer, T.K. (1995) *The Trouble with Computers*. Cambridge, MA: MIT Press;
Gibbs, W.W. (1997) "Taking Computers to Task," *Scientific American*, July 1997;
Brynjolffson, E. and Hitt, L. (1998) "Beyond the Productivity Paradox: Computers Are the Catalyst for Bigger Changes," *Communications of the ACM*, vol. 41, no. 8, August 1998, pp. 49-55.

2 RESEARCH APPROACH

2.1 The Mental Models Approach

The concept of "mental models" has been used in a number of research areas as an effective and insightful approach to studying the behaviors and beliefs of individuals and organizations. Mental models[14] can be defined as "deeply ingrained assumptions, generalizations, or even pictures or images" that influence how individuals interpret the world and take action.[15] The notion of mental models, introduced to the field of cognitive science by Philip Johnson-Laird,[16] is useful "for accounting for a subject's behavior in delimited domains."[17] The practice of describing people's beliefs and actions in terms of mental models "has been used extensively in cognitive psychology and cognitive science, for phenomena as diverse as how people solve brainteasers to how they troubleshoot steam boilers."[18]

The mental models concept has been used in organizational learning research to study individuals' beliefs about "what can or cannot be done in different

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[14] Johnson-Laird, P.N. (1986) *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*. Cambridge, MA: Harvard University Press.
[15] Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 8). New York: Currency Doubleday.
[16] Johnson-Laird, P.N. (1980) "Mental Models in Cognitive Science," *Cognitive Science*, 4, pp. 71-115.
[17] Gardner, H. (1985) *The Mind's New Science: A History of the Cognitive Revolution* (p. 368). New York: Basic Books.
[18] Morgan, M.G., Fischhoff, B., Bostrom, A., and Atman, C.J. (2002) *Risk Communication: A Mental Models Approach* (p. 22). New York: Cambridge University Press.

management settings."[19] Research findings in management give evidence that mental models form the basis of an individual's or an organization's actions and can limit the range of actions considered by the individual or the organization. For example, "insights into new markets" can "fail to get put into practice because they conflict with … tacit mental models" about the company, the market, the competition that are widely shared within the company.[20]

Peter Senge, an organizational learning theorist, puts it this way: "Like a pane of glass framing and subtly distorting our vision, our mental models determine what we see."[21] In this way, mental models "limit an organization's range of actions to what is familiar and comfortable"[22] and decrease its ability to consider and pursue possibilities outside of the established approach. To illustrate how "mental models shape our perceptions" with important consequence, Senge presents a case from the U.S. automotive industry:

> For decades, the Big Three of Detroit believed that people bought automobiles on the basis of styling, not for quality or reliability … The Detroit automakers didn't say, "We have a *mental model* that all people care about is styling." They said, "All people *care* about is styling."[23]

[19] Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 8). New York: Currency Doubleday.
[20] Ibid., p. 8.
[21] Senge, P.M. et al (2000) *Schools that Learn: A Fifth Discipline Fieldbook for Educators, Parents, and Everyone Who Cares About Education* (p. 67). New York: Doubleday.
[22] Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 186). New York: Currency Doubleday.
[23] Ibid., p. 176.

The Detroit automakers' taken-for-granted mental model of the American consumers' purchase decision criteria and the importance of styling ultimately caused them to lose significant market share by 1986 to German and Japanese automakers who won over a large number of American consumers with their value proposition of quality *and* style.[24] A similar example of limiting mental models can be found in many service industries "which still provide mediocre quality in the name of controlling costs."[25]

Efforts to take into account the mental models of a particular community are also found in the field of risk communication. In this field, the mental models lens has been used to study current beliefs of targeted populations regarding various health risks, including HIV/AIDS transmission, potentially adverse health effects of electric and magnetic fields, and exposure to radon in the home.[26] In the field of sociology, empirical studies have been conducted to examine individuals' mental models of marriage and gender stereotypes.

"The issue with mental models, Senge says, is ... whether they discharge routines in a person's life without them knowing it."[27] Consequently, undiscussed and "undiscussable"[28] mental models, those that "exist below

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[24] Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 176). New York: Currency Doubleday.
[25] Ibid., p. 177.
[26] Morgan, M.G., Fischhoff, B., Bostrom, A., and Atman, C.J. (2002) *Risk Communication: A Mental Models Approach*. New York: Cambridge University Press.
[27] Flood, R.L. (1999) *Rethinking the Fifth Discipline: Learning within the Unknowable* (p. 22). New York: Routledge.
[28] Argyris, C. (1994) "Good Communication that Blocks Learning," *Harvard Business Review*, 72 (4), pp. 77-85;
Argyris, C. (1991) "Teaching Smart People How to Learn," *Harvard Business Review*, 69 (3), pp. 99-109;
Argyris, C. (1990) *Overcoming Organizational Defenses*. Needham, MA: Allyn & Bacon.

the level of awareness"[29] and are not recognized as models but taken-for-granted as the way things are, can put a limit on an organization's range of actions and capacity for considering alternative ways of operating.

In the case of technology and organizations, "individuals' mental models tend to be oriented around established practices and norms, and may limit perception and understanding of an innovation."[30] In a study of the impact of the introduction of Lotus Notes, a collaborative groupware technology, into a consulting firm, Orlikowski found that users applied a "personal productivity tools" mental model to the Notes technology and thus did not appreciate "its collaborative nature" or use it as "a forum for sharing ideas."[31] Orlikowski concluded that the existing and familiar mental model of technology-as-personal-productivity-tools significantly inhibited user experimentation with the collaborative features of Notes and constrained the development of "changes in work practices and social interaction" that were supposed to be facilitated by the introduction of the groupware technology.[32]

2.2 Relevance to Educational Technology Research

Past research about technology use in education is generally characterized by an implicit and potentially misleading assumption that the impact of technology use in education, or any other human enterprise, is somehow not connected to the mental models that technology users have, when in fact it is

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29 Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 176). New York: Currency Doubleday.
30 Orlikowski, W.J. (1991) *Radical and Incremental Innovations in Systems Development: An Empirical Investigation of CASE Tools* (p. 23). Cambridge, MA: Alfred P. Sloan School of Management, Massachusetts Institute of Technology.
31 Orlikowski, W.J. (1992) "Learning from Notes: Organizational Issues in Groupware Implementation," CSCW'92 Proceedings, November 1992.
32 Ibid.

the mental models of the users (i.e. how they understand the nature and role of the introduced technology) that define the nature of the enacted technology practices and its impact on human affairs. For this reason, there are countless reports that describe how computers are being used to improve classroom learning and how computers are changing the way teachers interact with their students; yet for all the growing research on technology use in education, there has been little attempt by the education community to articulate and examine the important assumptions on which currently dominant educational technology practices are built.

There is an underlying rationale to current educational technology practice in schools. The central assertion of this dissertation is that in order for technology use to have a fundamental and purposeful effect on American education, and in order for improvements and innovations in educational technology use to be consciously developed, the rationale and taken-for-granted assumptions underlying current practices need to be surfaced and discussed.

My interest in employing the mental models lens is motivated by my finding that existing studies of technology use in education have not adequately focused on explicating the set of underlying assumptions, meanings, and expectations that educators and the general public have about the educational use of technology. "Failure to appreciate mental models" has limited the depth of change of many change initiatives.[33]

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[33] Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 177). New York: Currency Doubleday.

2.3 Research Objective

This research is an effort to characterize and examine prevailing beliefs underlying dominant technology practices in education. In this study, the concept of mental models is used as a lens for examining and eliciting understanding about the constructs that the majority of educators use to inform their interaction with the deployed computers in schools.

I hope my articulation of some of these underlying assumptions will move both advocates and skeptics of technology use in education toward a less superficial and more productive discussion regarding the role of computers in the education of children. This research does not attempt to exhaustively explore the set of mental models at work in educational practice, but rather it is an attempt to illustrate the utility of the mental models approach, to surface the dominant mental model in today's educational technology use, to show that alternative models can be considered, and to encourage an open examination within the education community. My effort in drawing attention to and articulating these underlying assumptions will have been worthwhile if it motivates more and more educators to consciously examine and evolve their own assumptions about how technology can be used in education.

3 THE DOMINANT MODEL OF TECHNOLOGY USE IN EDUCATION

3.1 Examining the Mental Model Underlying Current Practices

There is a set of assumptions underlying the more or less clearly circumscribed set of practices associated with computer use in the classroom. This set of assumptions stem from a particular mental model of how technology can be used effectively in education. I will refer to this mental model as “the mental model of computers as information technology and multimedia machines”. My purpose in the following sections will be to make explicit a number of implicit assumptions which underlie the practices and utterances and reflect the thinking of the majority of educational technology advocates and practitioners.

3.2 The Mental Model of Computers as Information Technology and Multimedia Machines

The proliferation of computers in American public schools over the past two decades has generated a widely shared expectation among educators, policymakers, and the general public that computer use will improve education. Public opinion polls indicate that Americans believe it is important for the nation’s schools to be equipped with computers. The pervasive mental model in the current education landscape posits that the primary value of computer access is realized in Internet access. Internet access is seen as a key resource in a teaching strategy that emphasizes the creation and use of multimedia presentations. The Internet is said to provide teachers and students access to up-to-date, “real world” information that is relevant to the day’s current events and to the cultural and social realities of teachers and students. Such up-to-date content is seen to have value not only in providing accurate factual information, but also in motivating teachers and students to personally connect with elements of the scholastic knowledge embedded in the curriculum. In order to fully leverage Internet access to current information and the multimedia modes of information presentation made possible by introducing computers into classrooms, it is argued that “technology integration” into the curriculum and existing teaching methods will be required. Not only is there value seen in the multimedia authoring possibilities brought about by widespread computer use in classrooms, it is often argued that the use of computers in education will raise up a generation that is computer literate in a world that is understood to be more and more driven by information technology.

In short, this mental model can be summarized in this quote: “Americans overwhelmingly understand that technology can play a vital role in education, especially in providing access to information and preparing students for the jobs of the future.”[34] These themes are enumerated here as a starting point for the useful process of surfacing the underlying assumptions of the mental model of computers as information technology and multimedia machines. It should be stated explicitly that this list is put forward only tentatively as a starting point for discussion and makes no claims to completeness.

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[34] Kent, T.W. and McNergney, R.F. (1999) *Will Technology Really Change Education? From Blackboard to Web* (p. 7). Thousand Oaks, CA: Corwin Press, Inc.

3.2.1 Access to the Internet

One of the ways the popular vision for educational computer use can be characterized is by the advocacy of Internet use in instructional activities. As a "Call to Action for American Education"[35] in the 1997 State of the Union address, President Clinton proposed that wiring every school in the United States to the Internet would improve education.

> We must bring the power of the Information Age into all our schools. Last year, I challenged America to connect every classroom and library to the Internet by the year 2000, so that, for the first time in history, a child in the most isolated rural town, the most comfortable suburb, the poorest inner city school, will have the same access to the same universe of knowledge.[36]

Complementing President Clinton's mandate, the federal government made an investment in wiring the schools. Through the Telecommunications Act of 1996, the Federal Communications Commission encouraged and supported technology spending in education with the implementation of the "E-rate" program. The E-rate program provided significant discounts for schools purchasing telecommunications services. Services covered by the E-rate include Internet access, videoconferencing services, high-speed data

[35] Clinton, W.J. (1997). The State of the Union address. United States Capitol. February 4, 1997. <http://www.whitehouse.gov/WH/SOU97>
[36] Ibid.

connections, phone service, and certain types of internal wiring and network equipment.[37]

When Congress laid the foundation for the E-rate program, policy makers cited several justifications for making such a substantial investment in bringing Internet access to schools. First, it was said that students can gain access to “a greater breadth and depth of up-to-date educational resources”[38] through the Internet. Second, it was argued that giving students access to computers and the Internet prepares them for “an economy in which three out of five jobs require a working knowledge of information technology.”[39] In line with President Clinton’s remarks, an emphatic appeal was made in conclusion: “Every child should be offered a fair shake in gaining access to a wealth of resources, opportunities for communication, and tools for personal expression.”[40]

“Let the future begin” was President Clinton’s remark when he and Vice President Al Gore kicked off California NetDay, a one-day statewide effort to connect California classrooms to the Internet.[41] California NetDay was held on March 9, 1996 and reportedly about 20,000 volunteers connected 3,000 schools to the Internet. The NetDay project was started in 1992 by Michael Kaufman, director of information technology at KQED public television

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[37] Carvin, A., ed. (2000) “The E-rate in America: A Tale of Four Cities,” Benton Foundation. <http://www.benton.org/e-rate/e-rate.4cities.pdf>

[38] Ibid.

[39] Ibid.

[40] Ibid.

[41] Kornblum, J. and Aguilar, R. (1996) “Clinton, Gore Kick Off NetDay96,” *CNET News.com*, March 10, 1996.

station in San Francisco who was also a former teacher, and John Gage, chief scientist at Sun Microsystems.[42]

On September 26, 1996, U.S. Government officials joined business and community leaders for a national NetDay. It was led by U.S. Secretary of Education Richard W. Riley and Assistant Secretary of Commerce Larry Irving. Irving remarked, "We can't afford to leave some of our schools behind – all of our children deserve access to the tools that will enable them to be full participants in the Information Age."[43] "This process of linking schools to the Internet brings vast resources to kids," said Gage.[44]

Enthusiasm for bringing Internet access to schools is rooted in the larger public concern that there exists a "digital divide" – a gap "between the information haves and have-nots."[45] It is seen that "the Internet has assumed an importance in Americans' everyday lives" and that "in the new Information Age" the Internet "promises to become the economic underpinning for all successful countries in the new global economy."[46] Consequently, it is considered an issue of public policy to close "the perceived gap between those who have access to the latest information technologies and those who do not."[47] "No one should be left behind as our nation advances

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[42] Long, K. (1996) "NetDay96: Getting California Schools Wired," *Seattle Times*, March 6, 1996.

[43] National Telecommunications and Information Administration, Department of Commerce (1996) Media Advisory Re: Launch of National NetDay, September 25, 1996. <http://www.ntia.doc.gov/ntiahome/press/926netdayma.htm>

[44] Kornblum, J. and Aguilar, R. (1996) "Clinton, Gore Kick Off NetDay96," *CNET News.com*, March 10, 1996.

[45] National Telecommunications and Information Administration (1999) "Falling through the Net: Defining the Digital Divide." <http://www.ntia.doc.gov/ntiahome/fttn99>

[46] Ibid.

[47] Compaine, B.M., ed. (2001) *The Digital Divide: Facing a Crisis or Creating a Myth?* Cambridge, MA: MIT Press.

into the 21st century, in which having access to computers and the Internet may be key to becoming a successful member of society."[48]

Research studies such as the 1997 report by the Educational Testing Service[49] documented inequalities in Internet access among schools and motivated public figures to advocate for making Internet connectivity widely available. U.S. Senator Bob Kerrey and filmmaker George Lucas described the importance of Internet access to education:

> In the dawning of the information age – where access to information will be the currency of power and knowledge – the definition of access for educational institutions should be expanded to include multimedia technologies and services ... Connecting every public school classroom and library to the developing superhighway is a legitimate goal of public policy ... We must all work together to ensure that the information superhighway is the road to educational excellence in America.[50]

Kerrey and Lucas pointed to universal Internet access as "the only way to attain equity of opportunity for teachers and students."[51] To "connect every classroom to the Internet" meant "students would then gain access to resources few schools can afford; they could then communicate with students

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[48] National Telecommunications and Information Administration (1999) "Falling through the Net: Defining the Digital Divide." <http://www.ntia.doc.gov/ntiahome/fttn99>

[49] Educational Testing Service (1997) *Computers and Classrooms: The Status of Technology in U.S. Schools*. Policy Information Center. <http://www.ets.org/research/pic/compclass.html>

[50] Lucas, G. and Kerrey, B. (1994) "Access to Education," *Wired*, Issue 2.09, September 1994. <http://www.wired.com/wired/archive/2.09/access.ed_pr.html>

[51] Ibid.

and experts around the world."[52] "It also will support the teachers" in enabling them "to access information and communicate with community members, peers, parents, students, and experts."[53]

Internet access is widely recognized as central to the future of education, and is often a prerequisite for entering into discussions about technology use in the classroom. Such technology is "assumed" by technology business leaders such as Bill Gates of Microsoft:

> Assume that the wireless network is there and you've got a very high-speed connection that lets you do not just text but video and audio as well ... As you are talking about homework, you can pull up different Web sites ... And assume in the front of the classroom that there's a big screen so you can browse the Internet ... A teacher could go to a Library of Congress site and get photos and text and go to other school sites and take and edit and add.[54]

Internet access promises not only access to a diversity and wealth of information sources, but also provides a diverse group of schools and communities, with and without wealth, access to the same world of information. It is argued that as technologies bring the "world" into the classroom, "the distinction between the classroom and the world begins to blur."[55]

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52 Lucas, G. and Kerrey, B. (1994) "Access to Education," *Wired*, Issue 2.09, September 1994. <http://www.wired.com/wired/archive/2.09/access.ed_pr.html>
53 Ibid.
54 "The Classroom of the Future" *Newsweek*, October 29, 2001.
55 Kent, T.W. and McNergney, R.F. (1999) *Will Technology Really Change Education? From Blackboard to Web* (p. 52). Thousand Oaks, CA: Corwin Press, Inc.

> Volumes of government documents are now available to any social studies classroom with an Internet connection. Students can access data from NASA, the current news from the *Washington Post*, or the latest stock market prices. The variety and sheer volume of information available free of charge through the Internet is staggering.[56]

The Internet is seen as an equalizer, a way of providing schools that have historically gone without resources access to the very best information, the same resources that their most wealthy counterparts are also enjoying: "Imagine if school children in a low-income neighborhood with precious few library books could use a modem-equipped computer and access all of the resources in the Library of Congress."[57]

In addition to having access to rich and diverse information via the Internet, the Internet is seen as a way for teachers and students alike to share their own information gathering, insight, and presentations.

> With today's computer technologies, teachers can produce their own Web pages or, perhaps more important, benefit from the development of Internet resources created by other teachers. Instead of being dependent on publishers and media developers outside of education, teachers can now use telecommunication technologies to create and

[56] Kent, T.W. and McNergney, R.F. (1999) *Will Technology Really Change Education? From Blackboard to Web* (p. 31). Thousand Oaks, CA: Corwin Press, Inc.
[57] Lazarus, W. and Lipper, L. (1994) *America's Children & The Information Superhighway: A Briefing Book and National Action Agenda* (p. 2). Santa Monica, CA: The Children's Partnership.

share their own content and resources.[58]

Students can also use the Internet to “conduct independent research” and “use multimedia to exhibit and illustrate their understandings.”[59] The vision of technology use in education expressed in government policies and the popular press is centered around access to the Internet.

3.2.2 Multimedia Authoring

“Multimedia is the integration of more than one medium into some form of communication or experience delivered via a computer.”[60] The synthesis of multimedia information culled from Internet sources into a computer-based presentation integrating text, graphics, sound, and video is becoming the envisioned mode of interaction with content in the classroom of the future. Multimedia authoring software programs are increasingly available in K-12 schools. “Employing relatively inexpensive desktop computers, users are now able to capture sounds and video, manipulate audio and images to achieve special effects, synthesize audio and video, create sophisticated graphics including animation, and integrate them all into a single multimedia presentation.”[61]

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[58] Kent, T.W. and McNergney, R.F. (1999) *Will Technology Really Change Education? From Blackboard to Web* (p. 158). Thousand Oaks, CA: Corwin Press, Inc.
[59] Ibid., p. 158.
[60] Reeves, T.C. (1998) *The Impact of Media and Technology in Schools: A Research Report prepared for the Bertelsmann Foundation* (p. 21), The University of Georgia, February 12, 1998. <http://www.athensacademy.org/instruct/media_tech/reeves0.html>
[61] Reeves, T.C. (1998) *The Impact of Media and Technology in Schools: A Research Report prepared for the Bertelsmann Foundation* (p. 21), The University of Georgia, February 12, 1998. <http://www.athensacademy.org/instruct/media_tech/reeves0.html>

Steve Jobs of Apple sees multimedia authoring as central to enabling a generation of students to be articulate in the major mode of communication of their day:

> One of our issues as a society going forward is to teach kids to express themselves in the medium of their generation ... The medium of our times is video and photography, but most of us are still consumers as opposed to being authors ... You should see the movies that kids and teachers are making now. They make movies to sell an idea and to lead a team. I can show you a movie made by a sixth-grade teacher with her kids about learning the principles of geometry in a way that you will never forget.[62]

Multimedia authoring activities with presentation software like Microsoft PowerPoint, along with web page design and video editing, are seen as effective ways to engage students in investigating content from the diverse sources available through the Internet. Students can use the Internet and multimedia authoring software for "accessing and interpreting information, organizing their personal knowledge, and representing what they know to others."[63] With the ability to do multimedia authoring, it is said that students can create "knowledge representations that reflect their own perspectives on or understanding of ideas."[64]

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[62] "The Classroom of the Future" *Newsweek*, October 29, 2001.
[63] Reeves, T.C. (1998) *The Impact of Media and Technology in Schools: A Research Report prepared for the Bertelsmann Foundation* (p. 3), The University of Georgia, February 12, 1998. <http://www.athensacademy.org/instruct/media_tech/reeves0.html>
[64] Ibid., p. 21.

Additionally, the content of multimedia presentations is said to be more interactive and engaging: “Multimedia can stimulate more than one sense at a time, and in doing so, may be more attention-getting and attention-holding.”[65] U.S. Senator Maria Cantwell commented on this and its relation to the retention of information and efficiency of learning:

> People who interact with information retain more of that information. The learning experience will include more multimedia. And that means better retention and better performance.[66]

Multimedia is seen to enhance learning by “providing [teachers and students] opportunities to construct and articulate meanings that in the traditional class would be limited to rendering and expressing in words only.”[67]

> Multimedia allows us to integrate more effectively the increasingly vast volume of information students need to learn. It also provides the vehicle for students to become adept communicators in a knowledge-based society.[68]

Saul Rockman, an education and technology consultant, asserted that such a mode of interacting with information develops an important skill in students,

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65 Reeves, T.C. (1998) *The Impact of Media and Technology in Schools: A Research Report prepared for the Bertelsmann Foundation* (p. 21), The University of Georgia, February 12, 1998. <http://www.athensacademy.org/instruct/media_tech/reeves0.html>

66 “The Classroom of the Future” *Newsweek*, October 29, 2001.

67 Woodbridge, J. (2004) “Digital Kaleidoscope: Learning with Multimedia,” *Technology & Learning*, January 1, 2004. <http://www.techlearning.com>

68 McBride, K.H. and Luntz, E.D. (1996) *Help! I have Hyperstudio Now What Do I Do?* (p. 11) Glendora, CA: McB Media Publishing.

the “ability to communicate and present in class.”[69] Creating a multimedia presentation helps students gain knowledge of a content area and simultaneously “enables students to become critical thinkers, problem solvers, more apt to seek information, and more motivated in their learning processes.”[70]

Designing a multimedia presentation is “a complex process that engages many skills in learners.”[71]

> The process requires learners to transform information into dimensional representations, determine what is important and what is not, segment information into nodes, link the information segments by semantic relationships, and decide how to represent ideas. This is a highly motivating process because authorship results in ownership of the ideas in the multimedia presentation.[72]

3.2.3 Studying Up-to-Date Information

One of the key offerings of the Internet is easy access to up-to-date information. The primary facet of up-to-date information is accuracy. The

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[69] Salpeter, J. (1998) “Taking Stock: What Does the Research Say About Technology’s Impact on Education? Interview with Saul Rockman,” *Technology & Learning*, May 1998. <http://www.techlearning.com>

[70] Neo, M. and Neo, K. (2001) “Innovative Teaching: Using Multimedia in a Problem-Based Learning Environment,” *Educational Technology & Society Education*, 4(4).

[71] Reeves, T.C. (1998) *The Impact of Media and Technology in Schools: A Research Report prepared for the Bertelsmann Foundation* (p. 24), The University of Georgia, February 12, 1998. <http://www.athensacademy.org/instruct/media_tech/reeves0.html>

[72] Reeves, T.C. (1998) *The Impact of Media and Technology in Schools: A Research Report prepared for the Bertelsmann Foundation* (p. 22), The University of Georgia, February 12, 1998. <http://www.athensacademy.org/instruct/media_tech/reeves0.html>

Internet provides access to current information about a world of shifting social, political, and economic realities. Compared to the offerings of a classroom dominated by information retrieved from textbooks, it is argued, the Internet offers content that is updated to reflect yesterday's changes.

Up-to-date information from the Internet is also seen to be more engaging for students. Current information and information gathered directly from observers and participants can take on an immediacy from its immersion in the "real world." This can connect both students and teachers to the content. There is also an increased possibility of understanding that the subject matter can be deeply connected to someone in the community or to a neighboring community. The fact that the information can be related to current events and happenings, to places and people who are working in the same "real world" that the students and teachers are in, can make the educational content sparkle. The "real world" is anticipated to become a more connected and intimate world by people like Professor Linda Darling-Hammond:

> All of our students will have personal laptops connected to the world with wireless networks. They will be keenly aware of events, places, and the experiences of people not only in their own community, but in communities from Europe and Africa to the Middle East and Asia.[73]

The diversity of sources and types of information offered through the Internet is greater than what would be readily available in a textbook, periodical, radio, television, or CD-ROM based classroom. The up-to-date

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[73] "The Classroom of the Future," *Newsweek*, October 29, 2001.

content of the Internet is not limited to digested content, but offers more and easier opportunities to access primary sources of information. This can come through a number of sources, such as electronic databases, reports, and publications by news sources, museums, foundations, universities, businesses and government agencies.

Cheryl Lemke, former Executive Director of the Milken Exchange on Education Technology, described how digital media uniquely meets "the educational requirements of today's information-based society."[74]

> Digital media is increasingly a reflection of our society – it is instantaneous, interactive, up-to-date, just in time, often visually stimulating and accessible round-the-clock. For learners it is stimulating and empowering, engaging them in learning, which deepens their understanding of core academic concepts ... We must create a learning culture which actively engages students in relevant, meaningful work within the study of the vast knowledge base that is constantly being reshaped by emerging technologies.[75]

3.2.4 Acquiring Scholastic Knowledge

According to education theorist Howard Gardner, scholastic knowledge is what children are introduced to when they begin school.[76] Scholastic

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[74] Salpeter, J. (1998) "Taking Stock: What Does the Research Say About Technology's Impact on Education? Interview with Cheryl Lemke," *Technology & Learning*, May 1998. <http://www.techlearning.com>

[75] Ibid.

[76] Gardner, H. (1991) *The Unschooled Mind: How Children Think and How Schools Should Teach*. New York: Basic Books.

knowledge encompasses knowledge about state capitals, about different parts of the human body, about the planets in our solar system, about stories in American literature, about names and properties of geometric shapes. Examples of technology use in education are centered around the acquisition of such scholastic knowledge. One such example is using the Internet to take a virtual tour – of historical sites, museums, geographical landmarks, ecosystems, cultural settings.

> Virtual field trips can be made to collections of museums. These sites provide varied resources for teaching and learning. Some offer ideas for student projects, provide lesson plans, teach how to do art processes, present images of art pieces, display timelines of historical periods, and give background information on artists, inventors, historical figures, or scientists. The Exploratorium has a section on its website, The Science Explorer, that has activities that can be done at home or in the classroom. Paintings can be printed for student analysis and interpretation from art museum collections. Students can also view and comment on paintings or exhibits in a computer room with a question guide. Occasionally, sites will offer brief videos that describe a process or time period. For example, the Metropolitan site has a current video selection on making illuminated manuscripts that illustrates this process. Video guides to accompany different collections are also available on some websites.[77]

[77] Devlin-Scherer, R. (2003) "Cost-Free Travel with Virtual Field Trips," *Technology & Learning*, September 1, 2003. <http://www.techlearning.com>

Another example of how technology is used for the acquisition of scholastic knowledge is the popular website-building competition, ThinkQuest.[78] ThinkQuest, started in 1996, is sponsored by the Oracle Education Foundation. Teams of students and their teachers compete by building websites on educational topics of their choice. These teams work together to research their subject matter and produce a creative educational website about the topic. According to the evaluation criteria, a ThinkQuest website "presents a topic in a manner that informs, clarifies, engages, and deepens understanding of vital issues." The evaluation criteria encompass a number of dimensions, including the quality of education content ("insightful, informative, and compelling content created for the site"), use of multimedia ("site effectively incorporates two or more thoughtful and useful multimedia resources that highlight the content and theme and enhance understanding"), writing ("writing incorporates superior and thoughtful ideas into well organized format and is free of any grammatical or mechanical errors"), and sources and citations ("superb collection of sources provided with accurate summaries, citations, and explanations").

Since 1996, 25,000 students worldwide have competed in ThinkQuest. Winning entries from years past can be accessed through the ThinkQuest library which currently contains more than 5,000 websites. There is a website created by a team of middle school students about farming. The website covers different types of farms (dairy farms, livestock farms, poultry farms, crop farms) and has pictures and descriptions of important machines used in farming. There is a website about the Chinese opera which covers the historical development of the art form, popular characters in the opera, different types of masks and costumes used, and different wind, string, and

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78 <http://www.thinkquest.org>

percussion instruments used in the opera. There is a website focused on the topic of energy.

> This innovative site takes users on a journey through time to learn about the long history, present, and future of energy. The site takes the user on a journey through time, beginning with ancient cultures and their methods of utilizing energy. All modern forms of energy are explained in detail, and specific modern components, such as fuel cells, batteries, and generators are taken apart piece by piece and explained in detail. Future forms of energy are explored.[79]

Another website focuses on poisonous plants and animals.

> This website contains valuable information on poisonous plants and animals. A wide range of species are described and classified according to their habitat and biological origin. Special attention is given to the behavior of venomous snakes and insects with advice on how to avoid a deadly bite. The site also reviews the application of some plant and animal poisons in medicine and pharmacy thus showing that dangerous substances can sometimes be useful.

Yet another website discusses the mail system of various places around the world.

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79 <http://www.thinkquest.org/library/winners.html>

> Take a fascinating whirlwind tour through the various postal systems in the world. Covering more than 60 postal systems around the globe, we will explore the colors and contrasts of international postal systems from the breezy isles of the Faroes to the exotic heartland of South Africa. See how unity in diversity exists as the vastly different postal systems worldwide cooperate together to form an international network, with air and sea-mail routes functioning as arteries and veins of this global mail circulatory system.

In addition, there are websites covering the spectrum of subjects traditionally taught in school, from geometry and algebra to social studies to science to the arts.

3.2.5 Integrating Technology into the Curriculum

Professional development for teachers is focused on the task of integrating technology into the school curriculum. Successful integration of technology into the school curriculum is seen as "matching technology use to the school's curriculum objectives."[80] It is argued that technology "should be directly embedded in an assessment-driven curriculum."[81] Teachers are encouraged to "visualize the curriculum" and "see how technology fits in" – in other words, to incorporate technology lessons into approved curricula.[82] It is also suggested that teachers familiarize themselves with web-based resources

[80] Kelleher, J. and Benson, L.M. (2002) "Connecting Technology and the Curriculum," *Technology & Learning*, August 1, 2002. <http://www.techlearning.com>
[81] Ibid.
[82] Ibid.

relevant to the curriculum that are available to them. Teachers are advised to "consider how curriculum standards, be they from the state, the district, or professional associations intersect with technology standards." The goal is to develop a "technology-rich and standards-based curricula."

In general, "technology integration" means using technology to deliver "subject matter in the curriculum already in place."[83] Practices implemented mainly involve "accessing the Internet for research ... viewing a video to gather more information" and using multimedia authoring software to "present their own ... construction of knowledge."[84] A meta-analysis study of 102 technology integration case studies (67 cases from K-12 education settings) identified the use of Internet information sources and multimedia software as common instructional components to all 102 case studies.[85] Such technology practices are viewed as examples of technology integration where technology is "integrated, engaging, and encourage student exploration", enabling students to "construct their own knowledge" on "topics of choice – everything from police vehicles to the Bermuda Triangle."[86]

3.2.6 Developing Computer Literacy

"The high-skilled, well-paid jobs of tomorrow demand the ability to use computers and telecommunications ... In the New Economy, every child without access to the Internet and without technology skills inherits a

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83 Woodbridge, J. (2004) "Technology Integration as a Transforming Teaching Strategy," *Technology & Learning*, March 1, 2004. <http://www.techlearning.com>

84 Ibid.

85 Johnson, D.L. and Liu, L. (2000) "First Steps toward a Statistically Generated Information Technology Integration Model," *Computers in the Schools*, 16(2), pp. 3-12.

86 Woodbridge, J. (2004) "Technology Integration as a Transforming Teaching Strategy," *Technology & Learning*, March 1, 2004. <http://www.techlearning.com>

lifetime of missed opportunity," wrote William E. Kennard, Chairman of the Federal Communications Commission.[87] "Computer literacy", a term coined by computing author Arthur Luehrmann, is seen as necessary for success in today's workplace: "As businesses lean more heavily on telecommunications and electronic technology, American workers must increasingly learn the ways of electronic communications just to carry out their day-to-day responsibilities."[88]

It is often argued that schools that have successfully integrated computers into their curriculum will be preparing students for an increasingly technological workplace.

> Technology can also dramatically increase the viability of students in the work force ... Workers fluent in technology will make the workplace more effective, increase productivity, and help ensure America's competitiveness in a global economy. The time to begin preparing our children for the realities of the new American workplace is now.[89]

The connection between today's technology education and tomorrow's employment has sifted all the way down to students, one of whom

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87 Kennard, W.E. (1999) "Equality in the Information Age" (p. 196) reprinted in Compaine, B.M., ed. (2001) *The Digital Divide: Facing a Crisis or Creating a Myth?* Cambridge, MA: MIT Press.

88 Lazarus, W. and Lipper, L. (1994) *America's Children & The Information Superhighway: A Briefing Book and National Action Agenda* (p. 7). Santa Monica, CA: The Children's Partnership.

89 Salpeter, J. (1998) "Taking Stock: What Does the Research Say About Technology's Impact on Education? Interview with Cheryl Lemke," *Technology & Learning*, May 1998. <http://www.techlearning.com>

commented in a *Time* magazine article from 1982, "We'll probably never get a job if we don't learn how to use computers."[90]

The public's motivation in supporting increased computer use in education has been driven by the conviction that computer literacy "will surely have a great influence on whether American children are competitive in the global economy of the Information Age."[91] The rationale underlying this conviction can be summarized as follows:

> Ever since the 19th century, schools have been the cornerstone of the effort to ensure that each American child has the opportunity to learn what he or she needs to be an active and productive citizen.[92]
>
> …
>
> The economy and the workplace are already being transformed by telecommunications technology. It is important for the nation to look ahead and actively prepare its youngest citizens to be full participants in the civic and economic life of the future.[93]
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> …
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> If America is to meet the challenges of an increasingly competitive global economy, the nation needs a workforce ready to compete. Not only are strong basic skills like

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[90] "Here Come the Microkids," *Time*, May 3, 1982.
[91] Lazarus, W. and Lipper, L. (1994) *America's Children & The Information Superhighway: A Briefing Book and National Action Agenda* (p. 14). Santa Monica, CA: The Children's Partnership.
[92] Ibid., p. 10.
[93] Ibid., p. 9.
[94] Ibid., p. 8.

reading, writing, calculating, and critical thinking necessary, but new “information skills” to help workers adapt to changing technologies and workplaces are essential.[94]

4 THE ONE-TO-ONE COMPUTING CONTEXT

4.1 The Maine Learning Technology Initiative

In recent developments, one-to-one computer access has become a reality for students and teachers in a number of school districts and states and the trend is quickly gaining support throughout the country. In 2002, Windschitl and Sahl reported that laptop computer programs "are one of the fastest spreading phenomena in American schooling today" and that "more than a thousand schools nationwide have committed themselves to some form of laptop computer initiative."[95]

A number of researchers have theorized that the reportedly limited and relatively unimaginative use of technology in education[96] can be remedied by schools' adoption of portable ubiquitous computing.[97] For instance, Stager

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[95] Windschitl, M. and Sahl, K. (2002) "Tracing Teacher's Use of Technology in a Laptop Computer School: The Interplay of Rayeliefs, Social Dynamics, and Institutional Culture" (p. 165), *American Educational Research Journal*, Spring 2002, 39, 1, pp. 165-205.

[96] Cuban, L. (2001) *Oversold and Underused: Computers in Classrooms.* Cambridge MA: Harvard University Press;

Oppenheimer, T. (2003) *The Flickering Mind: The False Promise of Technology in the Classroom and How Learning Can Be Saved.* New York: Random House.

[97] Papert, S. (1993) *The Children's Machine*. New York: Basic Books;

Rockman, S. (1998) *Powerful Tools for Schooling: Second Year Study of the Laptop Program*. San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/research2.rtf>;

Becker, H.J. and Ravitz, J.L. (2001) *Computer Use by Teachers: Are Cuban's Predictions Correct?* Seattle, WA: Paper presented at the 2001 Annual Meeting of the American Educational Research Association. <http://www.crito.uci.edu/tlc/findings/conferences-pdf/aera_2001.pdf>;

Russell, M., Bebell, D., and Higgins, J. (2004) *Laptop Learning: A Comparison of Teaching and Learning in Upper Elementary Classrooms Equipped with Shared Carts of Laptops* wrote, “Computing has failed to make a dramatic impact on classroom practice not because there are too many computers, but because there are way too few to do anything interesting.”[98] A recent comparative study of one-to-one laptop computing and shared mobile carts of laptop computers indicated that providing students with their own laptop computers did result in students using the computers with more frequency, motivation, and engagement.[99] In general, advocates of one-to-one computing have hastened to portray the availability of one-to-one portable computing as a unique context and an enabling catalyst for realizing the potential of technology in education.

“People’s ability to use an interactive device depends in part on their having access to some sort of a mental model.”[100] Therefore, understanding the mental model or metaphor that users adopt to guide their actions will help us to understand the “highly cohesive, self-referential systems of beliefs, goals, and rules that structure perspectives and organize activity” within a technology initiative.[101] This section reports an application of the mental models approach to the study of one large-scale technology initiative, the

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and Permanent One-to-One Laptops. Chestnut Hill, MA. Boston College: Technology and Assessment Study Collaborative.

98 Stager, G. (2000) “Dream Bigger” in Little, J. and Dixon, B., eds., *Transforming Learning: An Anthology of Miracles in Technology-Rich Classrooms* (p. 115). Bellevue, WA: Kids Technology Foundation.

99 Russell, M., Bebell, D., and Higgins, J. (2004) *Laptop Learning: A Comparison of Teaching and Learning in Upper Elementary Classrooms Equipped with Shared Carts of Laptops and Permanent One-to-One Laptops*. Chestnut Hill, MA. Boston College: Technology and Assessment Study Collaborative.

100 Moran, T.P. (1981) “An Applied Psychology of the User,” *Computing Surveys*, 13, pp. 1-11. As cited in Young, R.M. (1983) “Surrogates and Mappings: Two Kinds of Conceptual Models for Interactive Devices” (p. 35) in D. Gentner and A.L. Stevens, eds., *Mental Models* (pp. 35-52). Hillsdale, NJ: Lawrence Erlbaum Associates.

101 Tillquist, J. (1996) *High Concepts and Low Hanging Fruit: Using Information Technologies to Mobilize Organizational Change* (p. 17). Unpublished Ph.D. dissertation, University of California, Irvine.

Maine Learning Technology Initiative (MLTI). In 2002, more than 17,000 laptop computers were delivered to seventh-grade students and teachers in Maine's 243 public middle schools through the MLTI. In 2003, an additional 16,000 laptop computers were distributed to eighth-grade students and their teachers.

4.2 The Maine Learning Technology Initiative: Beginnings

"Maine man says computers can save America's schools" and "Maine man urges laptop revolt among students" were the captions to the front-page story of the *Bangor Daily News* on February 3, 1997. The story was about Dr. Seymour Papert, a Maine resident and a Professor at the Massachusetts Institute of Technology. In the story, Papert was said to have made this "bold pronouncement about the future of education": "There's a revolution afoot in the education of our children, and it's called the computer."[102]

On March 2, 2000, Angus King, the Governor of Maine at that time, held news conferences at the King Middle School in Portland and at the Gardiner Regional Middle School. King announced his proposal to provide every seventh-grade student in Maine's public middle schools with a laptop computer. In a piece he published on his website when the laptop proposal was announced, King wrote: "For more than 100 years, Maine has always been in the bottom third of states – in prosperity, income, education, and opportunity for our kids. In my 30 years of working on Maine economic issues, no idea has had as much potential for leapfrogging the other states and putting Maine in a position of national leadership than this one – giving

[102] Weber, T. (1997) "Signing on to Revolution," *Bangor Daily News*, February 3, 1997.

our students portable, Internet-ready computers as a basic tool of learning."[103]

An article published in *The Ellsworth American* on March 16, 2000 revealed that King's laptop proposal was inspired by a Maine resident.[104] The influential voice behind his proposal, said King, was Papert. The idea was hatched in 1998 as the two of them had lunch at the governor's mansion in Augusta. Over conversation, King brought up his idea to get more funding for computers in schools to improve the student-to-computer ratio in Maine. In reply, Papert reportedly said, "one-to-one is the only ratio that will make a difference."[105]

After the Maine laptop proposal was announced, Papert gave many speeches to legislators and public audiences in Maine. To illustrate how one-to-one access to laptop computers is necessary in order to transform learning in schools, Papert used the "computer as pencil" analogy. Papert would ask his audience to imagine a world where there were schools but there was no writing. Then one day, writing was invented and along with it, the pencil. At first, the schools decided to each get a pencil. Then they eventually secured a number of pencils and set up a pencil lab for students. Papert would contrast this imagined scenario with the reality that all students today have at least one pencil, and they use them "even before they know their ABC's – they

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[103] King, A. (2000) "From Lunchboxes to Laptops: Giving Our Kids Computers Will Change Their Future and Maine's," January 2000. <http://www.state.me.us/governor>
[104] Williams, G. (2000) "Blue Hill Man Inspired King's Laptop Proposal," *The Ellsworth American*, March 16, 2000.
[105] Personal notes from a talk by Papert at MIT Bartos Auditorium, July 9, 2002.

scribble, doodle, explore, express, create – the naughty ones even run with them."[106]

King's initial proposal in March 2000 precipitated two years of heated political debate and public discussion during which the proposal was both highly criticized and highly praised. In September 2000, the Task Force on the Maine Learning Technology Endowment was set up to assess the feasibility of "personal, one-to-one, classroom- and home-based access to appropriate computer technology for teachers and students."[107] In January 2001, the Task Force issued its final report, which unanimously called for the implementation of a learning technology plan that "goes well beyond a simple proposal to purchase machines."[108] The Task Force called for a technology program with a "focus on using computer technology as a tool to learn problem-solving, critical thinking, teamwork, and communication skills across all content areas."[109] Additionally, the Task Force recommended that there be "effective preparation, professional development, and training programs for teachers and other educators in the use and integration of learning technology tools in curriculum development, instructional methods, and student assessment systems" with an emphasis on "just-in-time, classroom-based approaches that focus on teacher-to-teacher assistance, exploration, and practice in integrating technology."[110]

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[106] Kyle, B. (2000) "Acute Pencil Shortage Strikes State Lawmakers," *Bangor Daily News*, March 30, 2000.
[107] Task Force on the Maine Learning Technology Endowment (2001) "Teaching and Learning for Tomorrow: A Learning Technology Plan for Maine's Future" (p. iv). State of Maine 119th Legislature, January 2001.
[108] Ibid., p. v.
[109] Ibid., p. iv.
[110] Ibid., p. iv.

The MLTI was approved by the Maine legislature in early 2001. The stated overarching goal of the MLTI is "to ensure a necessary level of access to technology, the Internet, and training and learning opportunities for all students and teachers at the middle school levels."[111] As stipulated in the statute, the Maine Department of Education appointed an advisory board of Maine educators and citizens and issued a request for proposals in September 2001. In December 2001, the Maine Department of Education signed a four-year, $37.2 million contract with Apple Computer, which included the purchase of iBooks, installation of a wireless network infrastructure, ongoing technical support and maintenance, and training workshops for teachers. Apple's contract with the Maine Department of Education is believed to be the largest single purchase of technology for education by a state.

The laptop computers and Internet connectivity have been deployed throughout Maine's public education system with the vision that technology capabilities will engender transformative changes in teaching practices. In its final report, the Task Force emphasized that "computer technology offers opportunities for self-directed, personalized learning projects that can tailor the curriculum to student interests and engagement, and allow teachers to facilitate active student learning rather than merely the rote transfer of information."[112] These new opportunities for "active student learning", asserted the Task Force, will "transform Maine into the premier state for

[111] Task Force on the Maine Learning Technology Endowment (2001) "Teaching and Learning for Tomorrow: A Learning Technology Plan for Maine's Future" (p. vi). State of Maine 119th Legislature, January 2001.
[112] Ibid., p. i.

utilizing learning technology in education in order to prepare students for a future economy that will rely heavily on technology and innovation."[113]

There has been much articulated hope for the MLTI to transform public education in Maine since the initiative's inception. J. Duke Albanese, Commissioner of the Maine Department of Education, believes that "making technology available, virtually all of the time, to all teachers and all students, simply changes everything [because] one-to-one access [ushers] in technology as an essential tool for teaching and for learning."[114] Matthew Oliver, superintendent for the school district of Piscataquis Community Middle School – a school in Guilford, Maine that went ahead of the pack and adopted one-to-one laptop computing for its eighth-grade students in 2000, sees the MLTI as "a wonderful opportunity to provide individualized learning for students."[115] Ed Brazee, member of the Maine Association for Middle Level Education, wrote in an open letter to Maine educators: "This is much more than a technology initiative. The MLTI is a learning initiative, giving students and their teachers access to information, people, and ideas in a way that traditional curriculum materials do not. The MLTI has the potential to change things for students and teachers to a degree we've rarely seen in schools."[116]

So it came to be that beginning with the 2002-3 school year, Maine's seventh-grade students and their teachers had a laptop computer for their own

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[113] Task Force on the Maine Learning Technology Endowment (2001) "Teaching and Learning for Tomorrow: A Learning Technology Plan for Maine's Future" (p. vi). State of Maine 119th Legislature, January 2001.

[114] Albanese, J.D. (2002) "Maine's Technology Initiative About Teaching and Learning," *MaineToday.com*, March 3, 2002.

[115] Nacelewicz, T. (2001) "Learning on Laptops," *Portland Press Herald*, January 25, 2001.

[116] Brazee, E. (2002) "An Open Letter to Middle Level Educators in Maine Re: An Opportunity: More Than It Seems," February 2002. <http://www.mamleonline.org>

personal use whenever they wanted or needed it – to scribble, doodle, explore, express, create, and perhaps even run with. Maine's eighth-grade students and teachers joined their ranks in the 2003-4 school year. Because of the MLTI, access to machines is no longer an issue for an unprecedentedly large geographical cluster of teachers and students. Digital technologies are no longer rare in Maine's middle-school classrooms.

4.3 One-to-One Computing Initiatives: Past Findings

In 1996, Microsoft Corporation and Toshiba America Information Systems launched the first large-scale, one-to-one laptop program in the United States, called the Anytime Anywhere Learning program.[117] There were 26 sites across the nation, "including both private schools and public school districts, for a total of 53 elementary, middle, and high schools."[118] Each participating student received a Toshiba notebook computer "loaded with Microsoft Windows and Microsoft Office software."[119] The program's objective was "to demonstrate that providing every student within a classroom with access to 'real world' business tools would produce substantial educational benefits by supporting learning anytime and anywhere."[120] Microsoft's Anytime Anywhere Learning program has been an

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117 Rockman, S. (1997) *Report of a Laptop Program Pilot, A Project for Anytime Anywhere Learning*. San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/resrch_1.rtf> As cited in Kerr, K.A., Pane, J.F., and Barney, H. (2003) *Quaker Valley Digital School District Early Effects and Plans for Future Evaluation* (p. 14), TR-107-EDU. <http://www.rand.org>

118 Rockman, S. (1997) *Report of a Laptop Program Pilot, A Project for Anytime Anywhere Learning* (p. ii). San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/resrch_1.rtf>

119 Rockman, S. (1998) *Powerful Tools for Schooling: Second Year Study of the Laptop Program* (p. vi). San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/research2.rtf>

120 Ibid.

important forerunner in one-to-one computing, impacting more than 100,000 students and teachers nationwide.[121]

In 1997, Saul Rockman, former Manager of Education Research at Apple Computer, released an evaluation report of the first year of the Anytime Anywhere Learning program. Rockman's report on the first year of the laptop program made use of "surveys, interviews, and site visits, and ... information from students, teachers, school and district administrators, and parents."[122] Rockman reported "strong and consistent" data "collected from questionnaires, interviews, and site visits."[123]

One important dimension the 1997 Rockman study explored was how the computers were being used. Rockman reported that the laptop computers were being used in schools in three primary ways: (1) word processing (writing papers/reports and note-taking); (2) developing presentations; (3) using the Internet.[124]

> Microsoft Word is the program most frequently used by both teachers and students; the program is used for a variety of purposes, including producing assignments, editing, creating brochures and graphic organizers, and taking notes. The Internet is the second most commonly

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121 Lowther, D.L., Ross, S.M., and Morrison, G.R. (2001) *Evaluation of a Laptop Program: Successes and Recommendations* (p. 1). Building on the Future NECC 2001: National Educational Computing Conference Proceedings. <http://home.earthlink.net/~anebl/lowther.pdf>

122 Rockman, S. (1997) *Report of a Laptop Program Pilot, A Project for Anytime Anywhere Learning* (p. 4). San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/resrch_1.rtf>

123 Ibid., p. 25.

124 Ibid., p. 19.

used tool, followed by Excel and PowerPoint.[125]

Rockman's study of the second year of the laptop program confirmed the findings of the first year study regarding how the laptop computers were being used. These findings were similarly reported in other research studies of one-to-one computing.

4.4 Established Patterns of Computer Use in the MLTI

In March 2003 an evaluation of the first semester of the statewide MLTI project was released by the Maine Education Policy Research Institute, "a nonpartisan research institute founded by the Maine State Legislature and the University of Maine System." The data collected include paper and web-based surveys of 731 teachers and 8007 students and interviews conducted with 152 teachers and 106 students. Findings regarding how the computers are being used within the MLTI echo patterns of technology use reported in past studies of one-to-one computing initiatives.

> By early December 2002, teachers indicated that they were using laptops in many different ways, but most often in conducting research for lessons, developing instructional materials, and communicating with colleagues ... [With] approximately 50% of teachers ... [using] the laptop[s] for these purposes at least a few times a week or more.
>
> ...
>
> Teachers are making rapid progress in incorporating

125 Rockman, S. (1998) *Powerful Tools for Schooling: Second Year Study of the Laptop Program* (p. viii). San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/research2.rtf>

> technology into instruction. They report being able to quickly access current information and locate websites that are beneficial to their students' learning. Teachers are becoming more sophisticated presenters of information and communicating more easily and frequently with students, parents, and colleagues. Some teachers report the perception that the role of teacher is changing from being dispensers of knowledge to facilitators or guides to information. Laptops and basic technical skills have enabled students to find the information they need, often with minimal teacher assistance.

The evaluation also reported that the leading use of the computers among the student population was for finding information, with 73% of the students reported using the laptops at least once a week for information gathering. Similarly, teachers report that the students are using the laptops primarily to use word processing software and to find information on the Internet.

It appears that, to an overwhelming majority of MLTI teachers, the laptop computers represented an information-rich resource and a digital tool for organizing and presenting information. Teachers generally viewed the laptop computers as a means for students to access information through the Internet and use digital tools to develop professional-looking presentations. Consequently, teachers associated the laptop computers' impact on teaching and learning with the information access and multimedia authoring capabilities of the laptop computers.

Consider the following representative remarks:

> I use the Internet once a week in conjunction with the *Kennebec Journal* to find U.S. [and] world sites. And I have used the Secretary of State kids' page to teach government.[126]
>
> As my class was reading an excerpt from *Twenty Thousand Leagues Under the Sea*, one of the students asked, "How far is a league?" I replied that I wasn't sure, but we could look it up later. Literally before the sentence was out of my mouth one of the students had looked it up and had the answer (a little over three miles). Similar scenes have happened countless times.[127]
>
> I am currently working with my accelerated students on a literary essay based on the [Mark] Twain book *Pudd'nhead Wilson*. With the informed use of the laptops, students have been able to virtually visit Twain's beautiful house in Connecticut, to have access to a wonderful quotation site that allows them to see the great writer's words on a number of subjects.[128]
>
> The iTeach Math site is superb! The lesson on comparing

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126 Silvernail, D. and Harris, W. (2003) *The Maine Learning Technology Initiative: Teacher, Student, and School Perspectives Mid-Year Evaluation Report* (p. 10). Maine Education Policy Research Institute. <http://www.usm.maine.edu/cepare/pdf/ts/mlti.pdf>

127 <http://www.mainelearns.org>

128 Ibid.

fractions and percents allows the student to visually see the relationship between all three. The use of the pies and bars Fraction Model has a variety of learning tools for students to expand their understanding of fractions.[129]

I showed crystalline structure with the Smithsonian Institute's fabulous Gem and Mineral Collection website. Students were asked to categorize the "type" (shape) of crystal by referencing a chart in the classroom.[130]

I have actively used student laptop computers to introduce and reinforce science concepts in my curriculum.

...

The accelerated science class visited a teacher site and looked at commonly held science misconceptions. For example, "Gases are not matter because most are invisible". Students were asked to tell what about the statement was wrong, and also tell why they believed someone could be confused by the concept. This activity generated fascinating conversation.

...

Looking ahead, I have found interactive physics websites that will be used later in the school year to simulate Newton's Second Law of Motion, Wave Mechanics, Simple

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[129] Silvernail, D. and Harris, W. (2003) *The Maine Learning Technology Initiative: Teacher, Student, and School Perspectives Mid-Year Evaluation Report* (p. 22). Maine Education Policy Research Institute. <http://www.usm.maine.edu/cepare/pdf/ts/mlti.pdf>

[130] <http://www.mainelearns.org>

[131] Ibid.

[132] <http://www.middleweb.com/mw/msdiaries/diaries02-03.html>

Machines, Projectile Motions, and Buoyant Forces. In each, students can control input forces and realize the impact each will carry on the outcome (very difficult concepts to demonstrate verbally or even in the lab).[131]

As part of a Social Studies unit on the elections, students were given the task to work as publicists for one of the gubernatorial candidates and create a slide show about the candidate. They used their laptops to research the issues, endorsements, and biographical information. Everyone was motivated to get the research done so they could learn how to create a slide show. At the end of the week, students were able to watch slide shows on the various candidates. And the really cool part for me was correcting their slide shows in the comfort of my own home – they e-mailed their completed projects to me!

Goodbye, Overheads. Hello, PowerPoint! I've been impressed with the quality of our 7th and 8th graders' PowerPoint presentations for their classes. I decided to venture out on that limb myself. I watched their teachers and our computer coordinator, asked a few questions, and got started. Of course it took me more time than simply updating my old overheads, but the results were well worth the effort. I found that creating the PowerPoint slides really engaged me in thinking through my presentation. Planning, arranging, and animating the cards really engaged my mind much more actively than even word processing had, and

> this didn't even include the possibilities of sound and video. An added bonus was that I could send the whole presentation to a colleague for review and feedback via email. I receive the feedback within 24 hours and made a few changes. Then it was ready to go. But that's not all. My experience with using technology as a tool definitely supports my observations that technology can help students to be more engaged in learning that is meaningful, skilled, and fun![132]

To summarize, teachers own descriptions of successful uses of the laptop computers revolved around these seven themes:

1) Teaching with the Internet – One-to-one laptop computing has provided teachers with a way to give their students immediate and easy access to a variety of sources of up-to-date information including virtual tours, images of historical documents, and interactive simulations.
2) Creating multimedia presentations – The laptop computers enabled teachers to incorporate multimedia presentations into classroom instruction for the purpose of communicating a topic to students or as collaborative student class projects on various topics.
3) Sharing teaching resources – The wirelessly connected computers gave teachers a convenient way to share information and teaching resources, located or created, with one another.
4) Teachers engaged in technology learning – Teachers reported becoming more engaged in learning about technology, such as how to

use Internet search engines and e-mail and create PowerPoint presentations, webpages, and iMovies.

5) Writing with the laptops – Teachers perceived a marked improvement in student writing which was attributed to the word-processing capabilities of the laptop computers.
6) Reaching students with special needs – Teachers remarked that the laptop computers helped students with special needs, especially in areas of writing, attentiveness, and organization.
7) Enhancing the curriculum with technology – Teachers used the laptop computers to support the teaching of the curriculum by using the Internet to find new resources for lessons and to teach students how to research information.

One teacher summarized how the laptops were used for all of the core subjects at his school during the first year of the MLTI:

> [The lead teacher's] strategy introduced students to the capacities of the laptops by integrating their use into everyday curriculum in each subject area ... With the completion of this group of skill building lessons, our teachers have become better at teaching with the laptops.

Across the school, computer use was integrated into the existing curriculum in five subject areas:

- English: Students learned the basic components of

[133] <www.bangorschools.net>

the laptops. Students also learned the AppleWorks word processor while completing writing assignments.

- Social Studies: Students learned research techniques available through the World Book Encyclopedia.
- Reading: These classes were the avenues used for the teaching of the FirstClass e-mail software. Teachers gave assignments via e-mail; students responded through e-mail.
- Math: Students employed the spreadsheet component of AppleWorks to enter data from surveys. The information was graphed in various formats for interpretation.
- Science: Students were assigned topics to research using Internet Explorer.[133]

Even in expressing issues of challenges and concerns regarding the one-to-one computing initiative, teachers remain focused on Internet use, citing issues such as finding strategies for using the Internet for research, not having enough time to explore Internet possibilities, and evaluating the trustworthiness of Internet sources of information.

One of the lead teachers in the MLTI, a library media specialist, put together a list of concerns and challenges that emerged from discussion with other teachers during the second year of the MLTI.

Top topics that MLTI teachers want from their library media specialists:

1. Web site evaluation – including who wrote it, how to find out who wrote it, document date and how to find it, web pages vs. web sites vs. home page, hoax site.
2. Search engine use – including comparing engines vs. subject directories, use of searchengines.com for various types of search engines, focus on using more than one engine, help menus, search terms and Boolean logic, use of paid hits in search engines.
3. World Book as the first source for who/what/where/when and how (basic knowledge and comprehension questions). How to effectively use the iBook version of World Book.
4. Preparing to search – including developing questions to search, how to take a critical thinking level question (evaluation, synthesis, application, analysis) and develop the knowledge and comprehension questions to get the information to help you answer the higher level research question, developing the key words needed to search, picking the best resources to search first, understanding when to use print vs. database vs. web resources, how to write "good" questions.

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[134] Grant, N. (2003) "Top Topics that MLTI Teachers Want from Their LMSs," published on the Maine Association of School Libraries website, February 2004. <http://www.maslibraries.org/resources/MLTIresources.html>

5. Plagiarism – including the why not to copy, how not to copy, when to use quotes, how to use citations and footnotes, fair use and educational use of others works, how to do own work in multiple formats (words, art, music).
6. Organizing information – how to do that, what styles of organization to use when (alphabetical, chronological, topical, prioritized – I forget the others!)
7. Bibliographies – biblio vs. works cited, styles of (MLA vs. APA, etc.), electronic automated bibliography use, annotated, justified.
8. Technical writing
9. Interviews – including preparing for, how to conduct, face-to-face vs. electronically, how to write up
10. How to get help – including: "How do I know when I need help?" "Where do I look for help?" "Who do I ask?" "How do I evaluate the given help?"
11. Web sites to guide research by 7th and 8th grades iBook users.
12. List of Portaportals and web sites from Maine middle school librarians.[134]

Descriptions of technology use within the MLTI provided by students reinforced the teachers' stories. Using the Internet, in contrast to textbooks, to conveniently research up-to-date information and making multimedia presentations were frequently mentioned. An evaluation report released in the latter part of the first year of MLTI one-to-one computing implementation similarly reported that the leading use of the laptop computers among teachers and students was finding information on the Internet.[135]

4.5 Beginning Influences and Institutional Expectations

In a technology initiative, “beginnings are of special importance because they constrain what is learned about the technology.”[136] I reviewed the initial communication about the laptop computers issued from the State in 2000, the technology strategy pursued in demonstration schools, ideas for computer use featured at MLTI teacher training sessions and Department of Education teacher meetings, and the established work of SEED, an organization that has worked with computer-using teachers in Maine since 1992, also the provider of MLTI teacher training. Collectively, these institutional voices and influences served to reinforce expectations for the use of the laptop computers and worked to structure perspectives and technology practices of the MLTI teachers.

One-to-one laptop computing, the Internet, and multimedia-authoring applications were bundled together in these institutional messages to Maine teachers. First, communication from the Governor’s office regarding the laptop initiative highlighted Internet access as a key focus. Following in that

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[135] Silvernail, D. and Harris, W. (2003) *The Maine Learning Technology Initiative: Teacher, Student, and School Perspectives Mid-Year Evaluation Report*. Maine Education Policy Research Institute. <http://www.usm.maine.edu/cepare/pdf/ts/mlti.pdf>

[136] Weick, K. (1990) “Technology as Equivoque,” in Goodman, P.S. et al, *Technology and Organizations*. San Francisco, CA: Jossey-Bass. As cited in Tyre, M. and Orlikowski, W. (1993) “Exploiting Opportunities for Technological Improvement in Organizations” (p. 18), *Sloan Management Review*, Fall 1993, pp. 13-26.

direction, demonstration schools, playing a leadership role in the MLTI, began to use the laptop computers one semester before the rest of Maine; their uses of the laptops focused on the Internet and presentation tools that came packaged with the Apple iBooks. Similarly, the official MLTI teacher training provided to teachers as part of the contract with Apple Computer emphasized the use of software applications for classroom presentations and Internet use for information gathering. At these MLTI teacher training sessions, SEED – a local teacher development organization in technology and education – distributed its catalog of project ideas, which consisted predominantly of Internet-based activities. Teacher meetings organized by the Maine Department of Education during the school year also put emphasis on various web-based resources for teaching specific subject areas.

4.5.1 State Communication about the Laptops

In March 2000, shortly after Governor King's proposal of the laptop initiative, the State's Commissioner of Education, J. Duke Albanese, sent out an informational letter to all superintendents, principals, and school board chairs. In the letter, he outlined the basic financial and hardware aspects of the computers "capable of Internet access, word processing, mathematical computations, and spread sheets."[137] He attached to the letter a question and answer publication from the Governor's office. In that publication, the purpose of the initiative was stated as "bridging the 'digital divide'," as the "Internet-ready, portable computer" to be distributed to every student would

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[137] Albanese, J.D. (2000) Informational Letter #36. <http://www.state.me.us/education/edletrs/2000/ilet36.htm>

provide “access to this critical technology” that “too many families do not have … at home.”[138]

> The key idea is to move computers and the Internet from the lab into classrooms and homes. Students won’t have to wait for a machine in the lab that’s open only during school hours; they can research topics on the Internet, work on ongoing projects, or do homework with these machines in the classroom, on the bus or at home.
>
> …
>
> It is an absolute certainty that the jobs of the future, in every area – manufacturing, services, healthcare, retail, government, education, everywhere – all will involve computer and Internet literacy. Those individuals and societies that are the most competent and at ease with this technology will be the most successful.[139]

The Governor’s question and answer stressed that there will be “professional development for teachers in the area of integrating technology and the Internet into the curriculum.”[140] There were three main areas where the technology was expected to influence the classroom and curriculum.

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138 Albanese, J.D. (2000) Informational Letter #36. <http://www.state.me.us/education/edletrs/2000/ilet36.htm>

139 Ibid.

140 Ibid.

> We envision three basic functions: word processing, math (spreadsheets, data manipulation), and, perhaps most important, e-mail and access to the Internet.[141]

The Internet was again mentioned as having an influence on the nature of the classroom, as the one-to-one laptop distribution "will enable computer- and Internet-based research assignments and exchanges with teachers and fellow students."[142]

4.5.2 Demonstration Schools

In the spring of 2002, eight months before the launch of statewide laptop distribution, nine schools received early delivery of laptops for some of their seventh-grade classrooms. These demonstration schools were to provide "technical validation of the program" and were to run ahead of the statewide program that would follow in order to explore and share "how [the computers] are being integrated into the curriculum."

> The demonstration schools are geographically spread across Maine based on the state's nine school superintendents' regions. They represent a range of school size and composition, including classrooms in several K-8 schools. As part of their commitment, demonstration schools will be open for other districts to visit for an average of one day per week, and schools will share

141 Albanese, J.D. (2000) Informational Letter #36. <http://www.state.me.us/education/edletrs/2000/ilet36.htm>
142 Ibid.

> experiences and student products with visiting teachers from the region and at regional and state conference sessions.
>
> …
>
> These schools, one in each region of the state, were selected to be Demonstration/Exploration Schools to receive an advance deployment of computers, in order to serve as learning laboratories and training sites for teacher professional development, as well as to test the technical reliability of the equipment. The shipments will total 675 iBooks, enough to equip several classrooms of seventh grade students at each school.

One teacher at each demonstration school was selected to be the Regional Integration Mentor (RIM), responsible for giving guidance and support to teachers within their school superintendent region. RIMs are viewed as the backbone of the MLTI project, especially during the first year, playing a key role in developing a statewide network for sharing experiences and lessons learned. Each RIM interacts extensively with the Teacher Leaders within their region to set up practices and procedures regarding laptop use. Each middle school in the MLTI has an appointed Teacher Leader, selected to play a leadership role in their schools on the basis of their ability to "move faster than others in appropriating the philosophy and/or methods offered by [the MLTI]."[143] There are 243 Teacher Leaders within the MLTI.

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[143] Maine Department of Education (2002) "Maine Learning Technology Initiative (MLTI) Manual" (p. 50). <http://www.state.me.us/mlte/portals/manual/Manual.doc>

The RIM at one of the nine demonstration schools commented in May 2002 regarding his experience with having the laptops in the classrooms:

> I believe that the vision of the program is that students will be able to engage in more meaningful, more current, more efficient and more “true” learning by using the laptops. This will occur through use of the software on the computer, Internet, presentation tools (e.g. iMovie, AppleWorks slide show, web pages), through telecommunications between each other, their teacher, and people in the “real world” and through use of the laptop as a piece of equipment. I think this is generally what is happening and what will happen.

4.5.3 MLTI Teacher Training

There were a number of regional MLTI teacher training sessions in the summer of 2002 and again in the summer of 2003. The sessions were run by Apple representatives and members of a local teacher development organization, SEED, which has been active in Maine since 1992. Most of the SEED affiliates were K-12 teachers themselves. There were five stated outcomes desired from the sessions in 2002:

> As a result of participating in this two-day session, participants will:
>
> 1. Understand the goals and purposes of the MLTI;
> 2. Know the basics of how to use their iBooks and the FirstClass [e-mail] system;
> 3. Learn some techniques for managing a classroom of laptops;

4. Explore ways to use their iBooks to stimulate inquiry in their classrooms; and
5. Further develop their school team's ability to learn and work together.

Of these goals, the basics of using the iBook occupied the largest part of the program sessions. Overall there were more than nine hours devoted to working with the laptops over the two days of training. On the second day these sessions began to deal with software applications that might be used directly in classroom presentations and projects and might also address the fourth goal and be used to "stimulate inquiry" in the classroom. The background of technology use in education was the focus of the first session, one-and-a-half hours long, the same amount of time devoted to the goals of understanding the "purposes of the MLTI" and "managing a classroom of laptops." Fifteen minutes were given to a "next steps for teams" session. In all, more than 80% of the time was devoted to learning how to use the laptop or the software packaged with it.

Continuing this practical focus, the literature distributed at the 2003 teacher training sessions was titled "Getting to Know Your iBook." Published by Apple, for a teacher training session run by Apple representatives, the training centered on computer use and software awareness. "Getting to Know Your iBook" was the primary literature for teacher training. The book goes through laptop start up, the inputs and outputs of the iBook, the track pad, the battery, the CD tray, shut down, log in, the Macintosh operating system, FirstClass (for handling e-mail), saving files, backing up files, Internet access and use, printing, the pre-installed calendar software, the AppleWorks suite of word processing, spreadsheet, database and presentation software, and iLife, Apple's integrated photograph and movie software. The instruction in the manual is practical but also highlights features that might be useful in classrooms that could be overlooked by teachers who are unfamiliar with the laptop and its ability to interface to other available technology. For example, "the real power of iPhoto is the ability to import and work with photos directly from your digital camera" and "a film camera ... can have photos developed onto a CD ... [that can be imported]". The manual does not deal with the training goals that fall outside of the basics of using the iBook and the software that comes with it.

There was also an MLTI manual published and distributed by the Maine Department of Education in the summer of 2002. Like the manual published by Apple, it was focused on the practical aspects of the MLTI, including topics such as what constitutes acceptable use of the laptops, how to deal with repairs and insurance, and what software comes packaged with the laptop. In this document, the vision for the educational impact of the laptops was articulated in this way: "The new tools (iBooks, FirstClass and Internet resources) available to each student will support ... [students developing the] skills required to be self-directed, independent, and life long learners."

In the 2003 teacher training sessions, there was a section designed to facilitate Internet use in information gathering. A reference card was given to the participants with question forms designed to elicit response and encourage "36 types of critical and creative thinking". The goal was to improve students' abilities to ask "good questions" in order to better leverage the Internet as a source of information. The session itself was spent largely on the use of the iBook to organize questions into different categories.

SEED's evaluation of the nine two-day MLTI teacher training sessions in 2003 took the form of an on-line questionnaire (there was no questionnaire from the 2002 sessions) consisting of six statements that the participant was to agree or disagree with at four different ranking levels and three short answer questions seeking an "overall evaluation", comments on the areas where the participant felt a need for (more) training, and an open answer section. Of the six statements, three were related to the training logistics (quality of the meeting space, the food, and the Internet connection) and three were assessments of the training:

1. I learned sample ways to begin to integrate iBooks into my classroom (No/Somewhat/Mostly/Yes)
2. I learned a process to use the iBooks to stimulate inquiry in my classroom (No/Somewhat/Mostly/Yes)
3. I learned how to access additional web based resources to support me and my students (No/Somewhat/Mostly/Yes)

4.5.4 SEED's Work Prior to the MLTI

At the teacher training sessions during the summer of 2002, SEED distributed its 2002-2004 "Cultivating Great Ideas" catalog featuring sixty project ideas developed by Maine teachers that had been selected to represent "high-quality teaching and learning with technology." Funded by the U.S. Department of Education Technology Innovation Challenge Grant, SEED has been working with teachers in Maine since 1992 to provide "a unique professional development network for teachers who want to integrate technology into their classrooms." The following excerpt of project ideas represent the approach to technology use in education that SEED has been facilitating for a number of years among teachers in Maine.

> Building a better understanding of the structure of the Internet and how to use it for research is the goal of this educational exploration. Students use the Internet via seldom-used methods to increase their knowledge of the medium, either independently or with guidance from a teacher. Discipline-specific content can be added to enrich individual curricula.
>
> Don't believe everything you read on the Internet. This unit helps students learn not only how to find information on history web sites, but also how to evaluate that information for accuracy. It ties together interdisciplinary content while teaching students to be critical thinkers and lifelong learners.
>
> While reading Chinua Achebe's *Things Fall Apart*, students form groups to research the history of Nigeria and Igbo culture, including the purpose of the mask in tribal rituals, family relationships, gender roles, food, art, music, stories, myth, coming-of-age ceremonies, and British colonialism. Students learn the basics of PowerPoint, and using a variety of sources from the Internet, gather digitized media to assemble their presentations.
>
> How can I convince a tourist to visit my country? That's

what students learn to do in this interdisciplinary unit that focuses on a European country of their choice. Working alone or in small groups, students research their chose country using a variety of sources including the Internet, electronic encyclopedias and other reference materials. They then create persuasive presentations for parents, students and teachers with scoring and comments provided by teachers and parents.

Students explore community events, history, economy, government, their geographical region, and create web pages for their school. Student groups are responsible for researching their topic, organizing and synthesizing information, finding historical photos and newspaper articles for scanning, constructing web pages and publishing as well as updating the page through the district server.

A website with information and images is the culmination of this study of other countries and how they compare to the United States. Using a variety of media, including books, the Internet and CDs, student groups research a country, create a written report, develop their websites, create posters, make recipes and dress in native costume for a presentation of their findings at an evening Celebration of Learning.

How can society achieve world peace? Who do you think should be Maine's next governor? How do you convince people to recycle? That's the art of persuasion! Students write speeches and create PowerPoint presentations using persuasive language to convince their audience of their point of view.

4.5.5 Department of Education Content Area Meetings

During the spring semester of 2003, one semester after the laptops became available in classrooms statewide, the Maine Department of Education organized a set of regional meetings called "Content Area Meetings". Similar meetings were also organized in the fall of 2003. The objective of the meetings was to provide a forum for MLTI teachers to share and discuss expectations, strategies for teaching with technology, and success stories. The meetings in the spring of 2003 did not result in much sharing among the teachers in attendance. The teachers felt that they had only just begun using the laptops for a short period of time and thus were reluctant to share their experiences. Most of the meeting time was then spent on introducing teachers to the software available on the laptops and various Internet resources for teaching different subjects.

During the fall 2003 meetings, there was much more sharing of experiences among teachers. The meetings yielded a summarizing document entitled "Teaching with iBooks: Ideas and Applications,"[144] written by a regional integration mentor. This document offers a list of recommended websites for teachers such as BrainPop, a website that provides "interactive videos,

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[144] Arsenault, K. (2003) "Teaching with iBooks: Ideas and Applications." <http://moore.portlandschools.org/ibook>

games, [and] lessons on a large range of topic areas"; the Maine Memory Network, a website containing a database of 3500 primary source documents about Maine; Discovery School, a website with "online quiz makers, puzzle makers, clip art galleries, lesson plans, units and great ideas on integrating technology"; and Blue Web'N, "an online library of 1700+ outstanding Internet sites categorized by subject, grade level, and format (lessons, activities, projects, resources, references, and tools)." The document also included a recommended strategy for "using the iBooks across the curriculum":

> Create a word processing document with embedded Internet links in them. For example, if you have some information that you want kids to know or find or would like them to do focused research, type out the question and then include a link as to where the students can find the information.[145]

"WebQuests" were also recommended as a way to integrate technology use in each teacher's curriculum area. According to this document:

> A WebQuest is an inquiry-oriented activity in which most or all of the information used by learners is drawn from the Web. WebQuests are designed to use learners' time well, to focus on using information rather than looking for it, and to support learners' thinking at the levels of analysis,

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[145] Arsenault, K. (2003) "Teaching with iBooks: Ideas and Applications." <http://moore.portlandschools.org/ibook>

synthesis, and evaluation.[146]

The document concluded with subject-area specific recommended websites for science, social studies, language arts, health and physical education, ESL (English as a Second Language), and math.

4.6 "Let's Give Programming to Children": An Alternative Voice within the MLTI

From August 14 to August 16, 2002, The First Maine International Conference on Learning with Technology – Learners, Laptops, and Powerful Ideas – was held at the University of Maine at Orono. The conference was designed "to discuss aspects of learning and transformational change with personal computers" as "a prelude to the September 2002 launch of the Main laptop initiative." The conference was intended to provide "a balance between technological innovation and practical classroom concerns... in order to prepare teachers facing this historic chapter in education." More than 200 educators from Maine attended the conference and were welcomed in the plenary session with keynote speeches by Seymour Papert and Alan Kay.

Papert opened his talk with these remarks, "We welcome you to a dream: Every kid will have a computer and that will change learning and living, notions of what childhood is about." He then posed a question, "What is meant by a computer?" He discussed the necessity of having one computer per student as opposed to one computer per classroom, much like each student is equipped with pencil and paper and is not faced with sharing such

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146 Arsenault, K. (2003) "Teaching with iBooks: Ideas and Applications." <http://moore.portlandschools.org/ibook>

a basic medium of communication. He commented on the consequences of one-to-one computing and saw as a primary benefit a change in the relationship between student and knowledge as students would be aided in knowledge acquisition and would be empowered in their new relationship with knowledge. “Children will become used to being in charge of knowledge; they will change their relationship with knowledge,” Papert said.

Papert then introduced the “idea of programming” as an illustrative example of how the computer can enable children to change their relationship with knowledge. He asserted that a child who is able to program a computer will be able to “do amazing projects.” To further illustrate, he talked about how the “powerful idea” of probability has been “disempowered” in school and reduced to the activity of calculating ratios because of the “paper-and-pencil technology.” In comparison, a child who can program the computer would be able to program “probabilistic behavior” and through that activity come to be connected with knowledge about the way things work in nature. Programming, said Papert, is also a way to connect children with cognitive science. Programming the computer enables children to make a formal articulation of their ideas and to see whether they work or not. According to Papert, these uses of the computer represent ways in which we can use the computer presence to bring into the educational system new kinds of content and go beyond “just [thinking about] how we can do the old stuff better.” Papert concluded, “Let’s give programming to children.”

Papert’s call to programming was followed by Alan Kay, who is credited as “the first scientist to describe a laptop computer.” Kay opened his talk with a description of his original idea of the “Dynabook”, conceived in 1968, as “a portable interactive personal computer, as accessible as a book.” Key to the

Dynabook idea, said Kay, is the phrase: "an instrument whose music is ideas." Kay recounted that his thinking behind the Dynabook was catalyzed by one memorable event: his visit to Papert's Artificial Intelligence Laboratory at MIT in 1968. There, he saw children learning to use the LOGO programming language that Papert had designed. The children, Kay observed, were doing simple programming and through the programming activity, they were "doing differential geometry in a natural way." In this way, the computer made it possible for children to learn "meaningful mathematics" and to understand "the foundations of some very powerful mathematical ideas." This experience demonstrated for Kay the potential of computers as an amplifier of children's learning: "[With the computer] children can think about many more things in the most advanced and rich ways." Kay stated that "dynamic simulations should be the most stable form of computation" and should lead to "a huge change in how ideas are argued, presented, and tested." He urged his audience to "remember that everything we do on the computer is a constructed illusion [so] we can decide what to construct."

As examples of how computation can provide children with "dynamic media for creative thought", Kay showed a programming environment in which children can construct a program of a fish following a feeding gradient. He also showed a program simulating an epidemic infection. He played a video of a group of fourth graders explored the ideas of uniform velocity and acceleration by programming an object on the screen to mimic the motion of a ball being dropped from the roof of a building. The screen object was then superimposed onto video footage of a ball being dropped from the roof of a building to show that it did accurately represent the ball's movement. The students, Kay asserted, learned the meaning of constant gravity and a host of other important concepts through this project. Kay concluded the plenary session by saying to the audience of Maine teachers, “Computers were made to be programmed.”

4.7 Case Studies of Teachers Pursuing Computer Programming

The following case studies describe the experiences of two individuals within the MLTI. These episodic accounts give evidence for the challenges faced by individuals pursuing a technology use outside of the currently established, Internet-centered approach, which in these cases is computer programming in the classroom.

4.7.1 Esther

When the MLTI started in September 2002, Esther taught in the seventh grade at a small K-8 school. Total enrollment at the school was 80 students. Esther, along with two other seventh-grade teachers, taught 17 seventh-grade students. Esther was responsible for science and social studies instruction and was also the homeroom teacher for the seventh-grade. As homeroom teacher, Esther was charged with the distribution of the MLTI laptop computers to the students. In the Principal’s office, unpacking a big cardboard box containing Apple iBooks, Esther expressed an excitement for the coming year.

> I think the laptop computers will give the students lots of good opportunities to learn all sorts of different things.

During the summer months that year, in anticipation of the start of the MLTI, Esther made an extra effort to attend any event related to the MLTI.

> If it has anything to do with the MLTI and I hear about it, I am there. I really want to learn as much as possible about how to use these laptops with my students.

Among the many MLTI events Esther attended was a workshop on LOGO programming held at the University of Maine at Orono. Esther had no previous programming experience but found the workshop interesting. It was something Esther wanted to try out in the classroom, along with other applications Esther learned about at the MLTI teacher training.

> I started keeping a list of cool things I want to try and do with my kids this year. At the MLTI training, they showed us how to use e-mail and how to participate in MLTI group discussions ... I wrote down some cool websites that have good resources for science and social studies that I will probably use with my kids ... the WorldBook encyclopedia is another good application ... there's a lot of interactive information there that my kids will like ... I also saw that you can get a scanner and digital cameras and work with photos and videos on the laptops ... I would like to get to that too. And the LOGO programming stuff I saw in Orono would also be cool to do with the kids.

Year 1 (2002-2003):

School had started for a few days before Esther could get the iBooks ready to be distributed to the students.

> That day, I remember the students could hardly sit still. I played with them a little and taught a lesson for twenty minutes … and I just acted like it was a normal day. The students didn't say anything … they just squirmed in their seats. Finally, I asked them, "Are you waiting for something?" and the whole class screamed back at me, "Yes! The laptops!"

In the first two months after the distribution of the laptops, Esther used the laptops frequently with the students. Esther also helped the other two seventh-grade teachers figure out ways to use the laptops in their classes.

> The other two teachers didn't go to as many MLTI meetings as I did so they come to me for help a lot. I try to encourage them to use the laptops as much as possible so we can share our experiences and figure out how to do things. These past months, we've used the WorldBook almost everyday to look up things related to our lessons. We've also used the Internet a lot. The English teacher had the kids look up information about the book they were reading … also, they found information about the author. I also found some websites that the Math teacher could use.

Over the next several months, Esther worked with the school's Principal to secure funding for the purchase of a digital camera and a scanner. Esther also enrolled the help of a fifth-grade teacher, who was also a SEED Developer, in starting a project with the seventh-grade students. Esther and the other two seventh-grade teachers received training from the fifth-grade teacher in how to use the digital camera and scanner and how to work with digital images and incorporate them into slideshow presentations and webpages. By the end of the school year, it was common for students to work together in Esther's class on projects involving the construction of slideshow presentations and webpages on various topics. Reflecting on the past year, Esther's enthusiasm for the laptops continued:

> It certainly has been fun and challenging to have the laptops this year. I'm quite happy with what we've done with them and I can't wait to be able to do more ... and we'll have more machines next year because of the MLTI expansion to the eighth grade. I think the other seventh-grade teachers also had a good experience with the laptops. The kids certainly love them. The other teachers and I agree that the laptops have had a positive impact on the students' learning ... the kids just seemed more excited to be at school ... and it's also been exciting for us teachers to learn to use the laptops along with our students. The other teachers were a bit timid at first about using the laptops and I was happy to be able to help them get through various anxieties and technical and logistical issues. It was great to be able to work together ... trying to figure things out together ... also getting help from the fifth-grade teacher.

> We've been able to do some good projects and we had a year-end open house for the parents and the community. The kids loved showing off their slideshows and webpages to their families. Overall, it's been a good experience. I'm hoping to stay in touch with [my colleagues] and maybe the eighth-grade teachers too over the summer so we can come up with more things to do with the laptops next year.

Year 2 (2003-2004):

Esther spent the summer thinking about what to do with the laptop computers for the coming school year. Esther started thinking about LOGO programming again when Esther met a teacher visiting Maine from Texas who had done LOGO programming in the classroom. Esther also spent time searching on the Internet for resources for teachers to pursue computer programming in their classrooms. From the Internet search, Esther discovered that a teacher at a nearby school, Ray, had been doing LOGO programming activities since the beginning of the year. Ray helped Esther download LOGO onto a laptop and Esther spent some time over the summer exploring LOGO commands and learning how to program in LOGO with occasional help from Ray. It was helpful for Esther to have a local person to go to as a resource for this new way of using the laptop computer.

> I wish that I had learned more about LOGO over the summer ... but you know life takes over. It's the summer. And [Ray] wasn't always available to answer my questions ... I have a lot of questions ... but I still got a lot of help ... I couldn't have gone this far on my own. Plus even if I did

> manage to learn more, I'm sure I would still be saying that I wish I had learned more. I couldn't get together with [the other seventh-grade teachers] ... the summer just went by so fast. I wonder if they've come up with more ideas for using the laptops. I can't wait to show them all this cool stuff I've been learning in LOGO.

There was no official MLTI training for seventh-grade teachers over the summer. There were MLTI training workshops for eighth-grade teachers, which were attended by two eighth-grade teachers from Esther's school. Esther was looking forward to hear about the eighth-grade teachers' experiences at the summer training.

> I bet they learned more things than I did last summer. I heard that the Apple people were showing how to use iMovie this year. I didn't get that last year. They only showed us WorldBook and AppleWorks and Internet stuff like WebQuests last year. [The eighth-grade teachers] better have good notes!

The second year of the MLTI began in September 2003. A few weeks after school started, one of the eighth-grade teachers showed Esther how to get started in iMovie. The two of them worked together with the Principal to get funding for the purchase of a digital video camera for the seventh- and eighth-grade classes. The eighth-grade teacher contacted a technology coordinator who was a personal friend and asked the technology coordinator to give an iMovie workshop to the seventh- and eighth-grade teachers. Esther enjoyed the iMovie workshop and started taking digital video footage of students' work and incorporating iMovie into classroom assignments.

Esther also contacted Ray who had provided her with LOGO help over the summer. Ray came to the school at the beginning of October to give a two-hour LOGO programming workshop to the seventh- and eighth-grade teachers at Esther's school. In Esther's eyes, the workshop went well.

> All four of the other teachers told me that they had a good time and that they wanted to learn more. We made plans with [Ray] to get together once a month for more LOGO programming workshops.

By the end of December, Esther started to express frustration about the other teachers' apparent lack of interest in programming.

> After the October workshop, I started doing LOGO in my class. Just a little bit here and there. I thought the other teachers would be trying it out in their classrooms, too, just like we did with the other stuff. But it seemed like they didn't even want to give it a try. I kept offering my help, even though I was just learning about LOGO myself. I didn't think it would be different from when we were learning to figure out things together last year.

Esther had set up another LOGO programming workshop with Ray in November. None of the other teachers showed up.

> I was so embarrassed. I thought we had all agreed at the last workshop to have another workshop again in a month. And for two weeks before the workshop, I kept pestering the other teachers to confirm that they would be coming. They all said that they would come. Maybe I shouldn't have scheduled it on a Saturday but I had checked with everybody about that and they said that it was fine. I felt bad for my friend [Ray] who had spent time preparing things for the workshop ... but [Ray] was really good about it ... [he] said that there's been no interest in programming at [his school] either so [for him] it's understandable that nobody showed up ... When I saw the other teachers on Monday, they just said "Oh, I'm sorry I couldn't make it." I said to them that if they really didn't want to come, they should have just said so. That would have been fine with me.

When school was back in session after winter break, at Ray's recommendation, Esther decided to pursue LOGO programming as an after-school activity with students who were interested.

> [Ray] suggested that I do an after-school workshop with kids for a week, which I did in January. I had ten kids who signed up and we stayed after school for an hour, sometimes we would go for two hours if the kids wanted to keep playing. [The other seventh-grade teachers] did stop by to visit and they said some nice things to me. But they still didn't seem all that interested to actually sit down and

> play around in LOGO.

By the time the school year came to an end, Esther had put aside LOGO programming and was mainly focusing on integrating iMovie into classroom projects.

> I think I just kind of gave up on programming. It seemed like nobody was interested in it. I couldn't talk about LOGO with anybody at my school. That put me in a really awkward position. It was a conversation killer whenever I brought it up so I stopped bringing it up ... I talked to [Ray] about it and [his attitude] is basically that you just have to go at it alone if you want to do something different from what other people want to do. But it's very difficult for me to have to isolate myself in that way. It's hard to work by yourself. It takes a lot of energy and you start to feel like nobody cares about what you're doing. I think there's a need to feel understood or at least to feel like your efforts are legitimized or appreciated in some way ... At one point, I just realized that I've put a lot of strain on myself, trying to convince people that programming is worth a try. Now I just say to myself ... It's not up to me to convert people's thinking ... I cannot be responsible for that ... Things have gotten better between me and the other teachers since I stopped doing LOGO ... Well, first of all, they don't avoid me anymore. People don't ask me questions like, "What's the point of doing this [programming]?" anymore ... which was kind of silly to me since we don't ask questions like that

> about any of the other things we're doing ... It's just simpler to focus on iMovie for now. I don't have to explain or justify anything to anybody. Maybe I'd pick up programming again some day ... because I still really believe there are real benefits in it ... but for now I'm just going to put it aside ... The other day, [another teacher] said to me, "We're so glad you're a team player now" ... and that made me so mad I didn't even know what to say [in reply] ... I wasn't trying to *not* be a team player ... I just think that we should try to do different kinds of things with the laptops. Maybe programming is just too different.

4.7.2 George

When the MLTI started in September 2002, George, a self-described "techie", had already been pursuing programming in the school context for the past several years.

> I had done some work as a programmer. I sort of learned about programming casually. I just sort of knew that it existed. When I first started working in schools, I didn't really know what to do. And then I started thinking ... these computers are enabling people to do things that have never ever been done before or even dreamed of ... so how come we're not using them like that in schools, you know? So it's been a long journey for me ... just trying to become more and more aware of what the possibilities are. I've basically become interested in this ... because I see a discrepancy

> between what people in the world are doing with computers and what schools are doing with computers. So I've sort of been working to just figure out what the possibilities might be since then.

George has worked at the same school for the past eight years. George is motivated in developing LOGO programming activities for mathematics education in particular. It has been challenging for George to introduce programming to the classroom teachers for their consideration.

> There seems to be a basic disagreement about ... what one might be trying to learn. It seems like ... writing a computer program to a lot of my colleagues, I think ... it's not their picture of how one should learn math. It doesn't feel like real math to them. People have a pretty different idea about what math is ... They don't have any reason to believe that [LOGO programming] has anything whatsoever to do with math and certainly not with their curriculum and certainly not with test results. Most teachers don't even know what programming is. Or teachers don't think they can do it ... [Programming] is quite different from what people are used to ... and it *is* hard for them. But I feel like my colleagues have not even seriously considered teaching their kids programming ... People almost bristle a little bit when you suggest programming as a possibility.

Reflecting further on possible reasons as to why the classroom teachers at the school find it difficult to consider programming as an instructional activity, George said:

> There are a lot of factors that make it hard to do this. First of all, [the iBook] is a consumer device. It's not made to require computer science to operate. We also have a very subject-driven type of approach. In public schools, I don't know if there is much that is not subject-driven. It's hard for teachers ... where you have a very subject-driven approach, where you have certain time schedules or slots, you have to deal with the curriculum, you have to pay some attention to test scores.

During the 2002-2003 school year, George was able to generate some interest in programming among a few classroom teachers.

> I had a couple of teachers who were interested ... because they see that it's possible to do a project [with programming] ... I did a project last year [2003] where we simulated dice rolling ... I did this in LOGO ... and we used LOGO to make our own graphs to keep track of the results ... and we investigated a bunch of probability questions and issues with that program. And we also ... when we were studying sequences and series ... we did sort of a Galileo experiment with balls rolling ... so that we could sort of start to think about how balls speed up and what happens over different frames of time. And I think the teachers

> started to realize it was real math that we were doing.

However, George was disappointed that the teachers' interest did not lead to more initiative on the teachers' part to pursue programming activities.

> They're not independent at all. To teachers, the programming and science experiments ... seem quite overwhelmingly hard. I would say, from my own point of view ... they sort of think they need me ... to do everything ... all the time. They don't really develop new things on their own ... they wait for me to think of something to do ... I don't know how to deal with that.

Fundraising has been key in allowing George to continue to pursue and promote programming at the school.

> I've had to go and raise my own source of money so that I can take the time to work out all kinds of things for people. Fundraising is a lot of trouble.

George also expressed frustration at the reality of having to work alone on pursuing programming.

> When I'm working on these [programming] projects ... I get a "super-abundance" of ideas for projects ... but I'm just one person ... when it comes down to getting them to fit into curriculums, and to be interesting to kids, and to be do-able in a certain amount of class time, and so on ... I'm

> finding that to be quite a challenge ... with me working by myself. I can spend my whole life working on these projects, you know, and still I would never get enough worked out. It's very, very time-consuming and very, very challenging for me.

George believes that people are more receptive when programming is presented in non-classroom settings. George has used after-school and weekend workshops to garner more administrative and parental support. However, this has not successfully transferred to more openness on the part of classroom teachers to try pursuing programming activities in their classrooms.

> I've done programming in after-school and weekend settings. That's allowed kids to do activities they otherwise would not have [the opportunity to do]. The parents came by to watch and they told me they liked it. I got a bit more administrative support after that. One day I was talking to the principal and he said that he thought the kids were learning tons of stuff ... but I don't think he would have said the same thing if I was using class time ... no way. But with increased administrative support and money of my own, I can keep going. But what concerns me the most is the resistance from other teachers. They see it as something incompatible to what they are doing. I think they feel like it's something that a "techie" is trying to force on them.

George believes a significant part of the problem is the lack of community discussion about technological possibilities that could be pursued with the MLTI laptop computers.

> To tell you the truth, if you work in a public school, the kinds of questions I have ... in meetings, people don't discuss these sorts of things. People would say, "Yeah, we can just talk about this all day and we won't get anything for it." But I mean, if we'd only talk about it at school fifteen minutes a day ... it'd be a good thing. So generally anyone who's willing to discuss things, you know ... I don't get that many opportunities to think about these things with somebody else.

George also expressed frustration at what he believes to be an over-emphasis on Internet-based activities in the current educational technology landscape, leading to a level of complacency among MLTI teachers.

> I try not to be cynical about things ... but I'm getting to be pretty cynical, you know. Getting information from the Internet is the primary use of computers these days. The kids naturally, just on their own, use the Internet. There is just too much emphasis from the Education Department, from the MLTI people, from speakers, on all this Internet stuff ... things like the WebQuests. And if I see one more PowerPoint presentation, I'm going to lose it. Those things are occupying the space. People feel like they are doing enough with the computers. I would be really happy ... I

> really wish ... I would like to see teachers ... say to themselves, "There are lots of different people in the world and they do a lot of different things, wonderful things ... and I can't keep up with everything wonderful that they are doing ... but I'd like to try."

George, however, remains somewhat optimistic about the laptop computers having a positive impact on education in Maine. The simple fact that one-to-one computing is now the reality for Maine's teachers and students, George believes, increases the likelihood for future conversations about non-established laptop uses like programming in the classrooms.

> It feels to me like the attitude in Maine has changed in the last couple of years. There are certainly some attitudes changing. Teachers are thinking about computers belonging in the classrooms more now, maybe, than they were before. Certainly, having the one-to-one computers makes it possible at least to have some conversation ... about what else we can do with them. Before it wasn't even possible to ask this question ... that conversation ... the answer was always "We don't have enough computers to think about doing anything with them." Now that response isn't there anymore. It feels like the questions are becoming more ... available? The things that one might ask about computers in schools ... but it's just a feeling I have ... I don't hear it from other teachers. I do have a sense that things are getting better ... but I don't really know.

4.8 Challenges in Pursuing Computer Programming

As uses of the laptop computers in schools become routinized around the Internet and multimedia-authoring applications, individual efforts in pursuing a technology use that deviated from this approach are likely to not be supported and recognized as valuable. To illustrate this point, I presented case studies of two individuals within the MLTI. These individuals were interested in pursuing LOGO programming, a technology use that significantly departs from the Internet- and multimedia-oriented uses widely adopted among the overwhelming majority of MLTI teachers.

In the case of Esther, a position of peer acceptance and leadership turned into isolation as Esther attempted to include LOGO programming in the repertoire of laptop activities. While Esther's desire to "learn as much as possible about how to use these laptops" did not seem to be restricted to popular or officially promoted uses within the MLTI, Esther felt that her colleagues did not seem to share the same motivation to explore and experiment with as many kinds of technology usage as possible. Over the course of the first year of the MLTI, Esther's initiative in actively seeking out information and help with regards to laptop use created a collegial atmosphere among the teachers as they all learned to use the Internet and to make slideshow presentations and webpages. However, the collaborative work relationship Esther enjoyed during the first year ("it was great to be able to work together ... trying to figure things out together") disappeared when Esther brought in LOGO programming ("it seemed like they didn't even want to give it a try"). Esther persisted in personal efforts to experiment with LOGO for a little while, but the sense of isolation ("I couldn't talk about LOGO with anybody at my school"; "It's hard to work by yourself") and emotional strain ("I've put a lot of strain on myself, trying to convince people that programming is worth a try") eventually led to Esther putting an end to personal experimentation with LOGO, replacing it with iMovie, a more accepted and officially promoted path to explore technology use in the classroom ("I don't have to explain or justify anything to anybody").

George's motivation in pursuing LOGO programming similarly stemmed from a desire to "become more and more aware of what the possibilities are" with regards to technology use in education. In contrast to Esther's surrender to peer resistance, George has remained motivated, perhaps fueled by the challenge of figuring out explanations for the resistance among teachers ("it's not their picture of how one should learn math"; "most teachers don't even know what programming is"; "[programming] is quite different from what people are used to … and it *is* hard for them"; "[the iBook] is a consumer device"; "it's hard for teachers … where you have a very subject-driven approach, where you have certain time schedules or slots, you have to deal with the curriculum, you have to pay some attention to test scores"). George has also come up with strategies that have enabled him to continue pursuing and advocating for an unpopular use of the laptop computers ("I've had to go and raise my own source of money"; "I've done programming in after-school and weekend settings"; "The parents came by to watch and they told me they liked it"; "I got a bit more administrative support after that").

George expressed optimism for the future ("teachers are thinking about computers belonging in the classrooms more now"). However, peer resistance remains the biggest and most troubling challenge for George ("I feel like my colleagues have not even seriously considered teaching their kids programming"). George, despite all efforts, has not been able to persuade other teachers to see LOGO programming as something that should be personally considered and experimented with ("they see it as something incompatible to what they are doing"; "I think they feel like it's something that a 'techie' is trying to force on them"). George expressed a longing for more collegial discussion ("people don't discuss these sorts of things") and less complacency ("people feel like they are doing enough with the computers"). The lack of peer support has also led George to experience a sense of isolation ("I'm just one person"), frustration with having to work alone ("I'm finding that to be quite a challenge ... with me working by myself"), and emotional strain ("I try not to be cynical about things ... but I'm getting to be pretty cynical") because of the choice to pursue computer programming.

The cases of both Esther and George are characterized by similar features:

1) Individual interest in exploration or innovation
2) Exploration or innovation that falls outside of the established patterns of technology use
3) Individual's recognition of peer resistance to exploration or innovation outside of the established patterns of use
4) Individual's sense of peer isolation as a direct result of attempts at exploration or innovation

The experiences of both Esther and George are marked not only by their encounter of a lack of peer support of the technology practice that they wish to explore, but also a feeling of peer resistance to any discussion of such alternatives and a feeling of isolation within their communities as a result of their desire to pursue an alternative use of the laptop computers. These two case studies demonstrate the way in which the mental model of computers as information technology and multimedia machines – which holds a dominant and privileged place in the MLTI technology practice and discourse – effectively creates a monopoly on how the laptops are to be used and even discussed in the communities of Esther and George.

4.9 MLTI as a Representative Example

The MLTI is a representative example of technology initiatives in education in general in the way that Internet- and multimedia-centered uses have become a pervasive and taken-for-granted part of normal operations. Teachers' and students' descriptions of their enacted technology practices, along with their descriptions of the impact that the laptops have had on classroom instruction, reveal that within the first years of implementation MLTI teachers' perspectives and interactions with the laptop computing environment have become cast in the Internet and multimedia paradigm.

The mental model of computers as information technology and multimedia machines was also evident in institutional communications and activities, constraining what is learned and seen as valuable about the introduced technology. As illustrated in the case studies of two teachers' attempts to pursue computer programming, established routines and ways of thinking about technology use act to impede individual efforts to explore and experiment outside of the established, routine uses.

In the MLTI, the presence of a widely-shared but unexamined mental model about how computers can be used in the classroom serves not only to organize individual, community, and institutional efforts in the initiative, but also serves to marginalize efforts that fall outside of the popularly endorsed technology routine.

5 DISCUSSION

5.1 Routine Use Limits Experimentation

Tyre and Orlikowski have argued that "the habits and assumptions surrounding [technology introduction in an organization] tend to become 'taken for granted' and built into standard operating procedures"[147] in a relatively short period of time following the initial implementation, in some cases after a few months or even a few weeks of technology use.[148] Their research documented that "once users became familiar with a new technology, it tended to become a 'taken for granted' part of normal operations."[149]

Citing their research study of more than one hundred technology implementation projects at "three manufacturing and service organizations in the United States and Europe" and existing research on Japanese companies, Tyre and Orlikowski stated that "this pattern was remarkably consistent across all of the projects analyzed ... whether the project involved five people or fifty, and whether the technology was familiar or a departure from current procedures."[150] A case study of Tech (pseudonym), a U.S.

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147 Tyre, M. and Orlikowski, W. (1993) "Exploiting Opportunities for Technological Improvement in Organizations" (pp. 13-14), *Sloan Management Review*, Fall 1993, pp. 13-26.

148 Tyre, M. and Orlikowski, W. (1994) "Windows of Opportunity: Temporal Patterns of Technological Adaptation in Organizations," *Organization Science*, 5, 1, pp. 98-118.

149 Tyre, M. and Orlikowski, W. (1993) "Exploiting Opportunities for Technological Improvement in Organizations" (p. 15), *Sloan Management Review*, Fall 1993, pp. 13-26.

150 Ibid., p. 14.

research university, indicated that "exploring or experimenting to learn about the technology" ceased "soon after initial implementation."[151]

> Instead, users quickly settled on a computing environment and tried to maintain its stability. As one Tech employee explained, few people even thought about making changes once they had become comfortable with the software: "It's just the way I do it."[152]
>
> …
>
> Even at Tech, where there were few system constraints on the changes that individuals made to their personal computing environments, users admitted that their own routines or habits tended to constrain further change. One user stated [regarding routines and habits] ... "Now they're ingrained."[153]

Explicating how routines and assumptions can become deeply entrenched, leading to a cessation of experimentation, Tyre and Orlikowski outlined the following dynamic in technology implementation initiatives:

> Successful implementation means that, over time, the technology becomes increasingly integrated into the [work] process. The new technology gets physically interconnected with the rest of the [work] process, and users learn to rely

[151] Tyre, M. and Orlikowski, W. (1993) "Exploiting Opportunities for Technological Improvement in Organizations" (p. 15), *Sloan Management Review*, Fall 1993, pp. 13-26.
[152] Ibid., p. 15.
[153] Ibid., p. 19

on it for [their] needs.[154]

Thus, experimentation "threatens to disrupt" the work process and "destroy the routines and procedures for using the technology that users establish over time."[155] In this way, user experimentation is limited by increasing routinization that occurs with experience: "The more experience that users gain with a new technology, the more they rely on established routines and habits."[156] Over time, "both the technology and the way it is used are eventually taken for granted."[157]

In the MLTI context, routine and taken-for-granted uses of technology have become established around Internet- and multimedia-oriented uses of the laptop computers. Examples of these uses include looking up information on the Internet or digital encyclopedia, creating multimedia projects in the forms of PowerPoint presentations, multimedia slideshows, and websites, using or creating Internet-based learning activities like WebQuests, and working with digital video footage in iMovie.

This is not to say that the statewide introduction of one-to-one laptop computing and the widely adopted Internet- and multimedia-centered uses have not produced valuable changes. Dr. Anne Davies in her year-long study of one MLTI school reported that, "the way students learn is changing."[158] More specifically, "teaching is more project-based and learning is more

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154 Tyre, M. and Orlikowski, W. (1993) "Exploiting Opportunities for Technological Improvement in Organizations" (p. 19), *Sloan Management Review*, Fall 1993, pp. 13-26.
155 Ibid., p. 19
156 Ibid., p. 24
157 Ibid., p. 24.
158 Davies, A. (2004) *Finding Proof of Learning in a One-to-One Computing Classroom* (p. 107). <http://www.connect2learning.com/cp/publications/assessment_resources/proofoflearning/>

collaborative." She also found that students appeared to be motivated to complete assignments using the laptops and appeared to be "more willing to help each other."[159]

> Access to current, relevant information and resource materials appears to be making a difference - students are more informed, they are learning about different things, and they are showing what they know in different ways.[160]

Similarly, Debbie Jamieson, a teacher at Pembroke elementary school, reported that the laptops have changed "the teaching and learning dynamic in her classes."[161]

> Wireless access to the Internet ... provides unlimited access to a wealth of educational resources. Jamieson says that although students live in a town where the closest store or bank is 30 miles away, the world's most exotic locales are instantly accessible through a "virtual field trip" online.
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> ...
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> She adds that the entire tenor of her classroom has shifted since the laptops arrived. "There's been a huge improvement in the kids' self-esteem. They feel like 'I have this tool, and I can find this material,' which is really

[159] Davies, A. (2004) *Finding Proof of Learning in a One-to-One Computing Classroom* (p. 107). <http://www.connect2learning.com/cp/publications/assessment_resources/proofoflearning/>
[160] Ibid., p. 107
[161] "Profiles in Success: Maine Learning Technology Initiative," Apple Computer, 2005. <http://www.apple.com/education/profiles/Maine>
[162] Ibid.

> empowering for them. The discipline issues have gone down dramatically, and the conversation in the classroom has become much more academic – the kids are showing each other where to find information for their presentations, and they're really collaborating," Jamieson says.[162]

In my inquiry of technology use in the MLTI, I encountered many conscientious individuals – teachers and people who work to support them in various ways – who diligently work to give students positive educational experiences. The introduction of laptop computers and Internet connection into Maine's middle-school classrooms did generate excitement and interest and motivated teachers and students to regularly use technology. Teachers are reportedly enthusiastic about using laptop computers in their classroom lessons and student engagement has increased while disciplinary problems have gone down.[163]

It was a little more than a decade ago that Professor of Education Larry Cuban predicted that computers would "continue to play a niche role in the education of American students."[164] For the past decade, limited access to technology and the lack of its widespread use by teachers were significant issues of concern. American schools have made significant progress with regards to these aspects of technology use: "During the last decade, as the Internet and multimedia technology became widespread, enthusiasm for the use of computers in schools also became more evident across the United

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163 Maine Education Policy Research Institute (2003) "The Maine Learning Technology Initiative: Teacher, Student, and School Perspectives," Mid-Year Evaluation Report, March 2003.

164 Cuban, L. (1993) "Computers Meet Classroom: Classroom Wins," *Teachers College Record*, vol. 95, no. 2, 1993, pp. 185-210.

States."[165] What I aim to communicate is that technology-enabled change is indeed happening in American education, but only along one particular direction, and that development has only been pursued from one paradigm, the Internet and multimedia paradigm.

5.2 Analogical Reasoning from Film, Radio, and Television

The mental model that organizes current thinking about technology use in education emphasizes information work. As Edward B. Fiske, former education editor of *The New York Times,* sees it: "Computers are very good at delivering information, and conveying information is an important part of education."[166]

Collins and Gentner have put forward the hypothesis that analogical reasoning is a major way in which people construct a mental model of a new domain.[167] That is, people rely on analogies from known domains to derive a mental model of how things work in an unfamiliar domain.[168] The analogies most frequently used to envision the educational utility of computers involve past classroom technologies like film, radio, and television. The following passage illustrates the prominence of such analogies in current thinking about the role of computer technology in education:

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[165] Anderson, R.E. and Ronnkvist, A. (1999) "The Presence of Computers in American Schools," Center for Research on Information Technology and Organizations, University of California, Irvine and the University of Minnesota;
Kleiner, A. and Lewis, L. (2003) *Internet Access in U.S. Public Schools and Classrooms: 1994-2002.* U.S. Department of Education, National Center for Education Statistics.
[166] Fiske, E.B. et al (1991) *Smart Schools, Smart Kids: Why Do Some Schools Work?* (p. 149). New York: Simon & Schuster.
[167] Collins, A. and Gentner, D. (1987) "How People Construct Mental Models" in Holland, D. and Quinn, N., eds., *Cultural Models in Language and Thought* (pp. 243-265). Cambridge: Cambridge University Press.
[168] Ibid.

> A significant minority of teachers have welcomed computers as an aid to learning and incorporated them in imaginative ways in their classrooms. These [teachers are the] serious users, like colleagues in earlier generations who welcomed film, radio, and television ... The educational potential of the computer is already apparent ... Computers are by far the most powerful teaching and learning machines to enter the classroom. Students and teachers can interact with computers in ways impossible with film, radio, and television. Depending on the software, preschoolers through graduate students can write and edit, learn languages, have a machine "tutor" in algebra, retrieve a great variety of information from electronic disks or distant libraries, receive E-mail from students a continent away, prepare multimedia reports, and use state-of-the-art technology in drafting, auto mechanics, and office work.[169]

5.3 Limits of Current Mental Model

According to Papert, the established technology routine in education has not been unfruitful, but neither has it succeeded in recognizing and utilizing the unique educational possibilities afforded by computation. Papert commented that computers are still framed in popular discourse as "essentially all about information."[170]

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169 Tyack, D. and Cuban L. (1995) *Tinkering Toward Utopia: A Century of Public School Reform* (p. 126). Cambridge, MA: Harvard University Press.
170 Papert, S. (2002) "Learners, Laptops, and Powerful Ideas", *Scholastic Administr@tor*, Fall 2002.

> When computers are used mainly as presentation tools, students miss out on the full potential of technology. The current school computer culture neglects to develop learning outside the limits of the informational sphere.[171]

Papert is quick to point out that "the established paradigm of computer usage in schools" is not inherently faulty or leading education culture in harmful directions:

> The school computer culture has not been a failure: It has worked wonders in terms of enhancing the ability of students to gather and express information. But education is about more than that.[172]

These sentiments echo what Papert had said more than a decade earlier:

> Thinking of the future as an information age certainly focuses on some exciting new developments. There is more access to more information than there has ever been before ... [But] the role that the computer can play most strongly has little to do with information.[173]

Papert then pointed out that "the danger of encouraging an information-centered approach to education" was more precisely "the danger of seeing the

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171 Papert, S. (2002) "Learners, Laptops, and Powerful Ideas", *Scholastic Administr@tor*, Fall 2002.
172 Ibid.
173 Papert, S. (1990) "A Critique of Technocentrism in Thinking About the School of the Future", E&L Memo No. 2, Massachusetts Institute of Technology. <http://lcs.www.media.mit.edu/groups/el/elmemo/2-90memo/>

most important aspect of education as the providing of information – or even the providing of access to information."[174]

5.4 Learning about Ecology with Computers: Two Examples

Given that "people's ability to use an interactive device depends in part on their having access to some sort of a mental model,"[175] the following two examples of technology-enabled activities undertaken for the similar purpose of promoting student learning about ecology give an account of how the technology and its context of use can be shaped by different mental models.

5.4.1 The Apple Vivarium Example

The Apple Vivarium program began in 1986 with Alan Kay as its principal designer. The Vivarium program was centered on "the ecology-in-a-computer concept"; children ages 6 through 12 at the Open School: Center for Individualization, in Los Angeles, worked to create dynamic simulations of animal life in order to study "strategies that help animals survive in their environments."[176] The children were able "to design animals and the simulated environments in which they live."[177] They also were "able to program the animals' mental and behavioral characteristics, such as what they eat, how they move, and so on, and then observe the animals' resulting

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174 Papert, S. (1990) "A Critique of Technocentrism in Thinking About the School of the Future", E&L Memo No. 2, Massachusetts Institute of Technology. <http://lcs.www.media.mit.edu/groups/el/elmemo/2-90memo/>

175 Moran, T.P. (1981) "An Applied Psychology of the User," *Computing Surveys*, 13, pp. 1-11. As cited in Young, R.M. (1983) "Surrogates and Mappings: Two Kinds of Conceptual Models for Interactive Devices" (p. 35) in D. Gentner and A.L. Stevens, eds., *Mental Models* (pp. 35-52). Hillsdale, NJ: Lawrence Erlbaum Associates.

176 Yaeger, L. (1988) "Vivarium History: The Vivarium Program." <http://homepage.mac.com/larryy/larryy/VivHist.html>

177 Ibid.

interaction with each other and with the environment."[178] Kay mentioned one example of an ocean life simulation done by students in a *Scientific American* article published in 1991:

> Clown fish is featured in an ocean simulation constructed by nine- and ten-year olds at the Open School. The fish repeatedly brushes up against an individual sea anemone to build immunity to its poisonous stings. After immunity is established, the fish can take refuge among the anemone's tentacles whenever a predator (here a shark named Jaws) is near. By constructing simulations, the children learn more about the challenges of being a clown fish and the benefits of symbiosis than they would if they engaged only in more passive activities – such as reading books and observing a fish tank.[179]

Kay used this project example to argue how children, and adults, "learn best when they can test ideas through simulation."[180] According to Kay, "the heart of computing is building a dynamic model of an idea through simulation."[181] The children can use "the simulation capability of their computers" to "construct models of their ideas."[182]

> Computers can go beyond static representations that can at

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[178] Yaeger, L. (1988) "Vivarium History: The Vivarium Program." <http://homepage.mac.com/larryy/larryy/VivHist.html>

[179] Kay, A. (1991) "Computers, Networks, and Education" (p. 140), *Scientific American*, September 1991, pp. 138-148.

[180] Ibid., p. 140.

[181] Ibid., p. 148.

[182] Ibid., p. 143.

> best argue; they can deliver sprightly simulations that portray and test conflicting theories. The ability to "see" with these stronger representations of the world will be as important an advance as was the transition to language, mathematics, and science from images and common sense.[183]

"There could be videodiscs showing plant and animal growth, and the students could have network access to data about crop yields, taxonomies of animals and plants, and so forth,"[184] Kay wrote. But why pursue this approach, he asked, "when the children can ... actually create whole worlds?"[185]

5.4.2 The Fading Footprints Example

During the first year of the MLTI, a project on ecology, involving 85 students and 7 teachers at King Middle School in Portland, became widely recognized and applauded as an exemplary use of computers to promote student learning. For three months, the interdisciplinary project engaged students in exploring the question, "How does diversity strengthen an ecosystem?" and was focused on the production of a field guide of endangered species in Maine. Each student worked to produce a species page for the guide, which was packaged by the students on a CD-ROM and ultimately sold through the Maine Audubon Society and the Children's Museum of Portland.[186]

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183 Kay, A. (1991) "Computers, Networks, and Education" (p. 148), *Scientific American*, September 1991, pp. 138-148.
184 Ibid., p. 143.
185 Ibid., p. 143.
186 Grant, D. (2002) "Fading Footprints", SEED.
<http://king.portlandschools.org/documents/fprints/begin.html>

The project, called “Fading Footprints”, was based on a similar effort undertaken five years earlier with several of the same teachers, in which a “field guide to life in [the] tidal pools of Casco Bay” was produced, bound, and published. With the increased access to computer technology provided by the MLTI, the teachers “intended to do more than simply [improve] a learning products packaging.”[187]

> The integration of multimedia technology with existing excellent practice opened up new ways to reach kids – through accessing broader categories of intelligences and learning styles; through providing integrated approaches to differentiated learning; through introducing students to skills and applications in electronic publication; through providing every student with a full color original “text” of the ecology unit that they themselves had authored – in a medium that they were used to paying for at the mall.[188]

“Direct instruction, cooperative learning, professional and student presentations, [and] class trips” were all a part of the Fading Footprints project, but central to the project was the educational strategy of “representing-to-learn,” where the representation made by the students, the field guide, served as “a core vehicle for acquiring knowledge and skills.”[189]

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[187] Grant, D. (2002) “Fading Footprints” (p. 8), SEED. <http://king.portlandschools.org/documents/fprints/begin.html>
[188] Ibid., p. 8.
[189] Ibid., p. 4.

The first month of the unit “was dedicated to instruction on the major themes and vocabulary of ecology.”[190] These themes included “understanding the life cycle, behavior, and structure of various organisms; demonstrating knowledge of the classification of living things; understanding how natural and artificial selection affects species over time.”[191] In the second month, research was conducted by the students through the school’s “electronic and bound research resources to collect information” on their assigned endangered species.[192]

The third month, writes the key developer of the project, “demonstrates most clearly how the integration of technology with effective instructional strategies can enhance learning.”[193] At this time the students put together their interactive pages for their endangered species. The laptop computers provided “a virtually unlimited canvass for the students to work on” and the field guide incorporated “beautiful color images made by students; video and audio recorded and edited by students; as well as unlimited pages of text.”[194] Those students “who finished ahead of their classmates began the work of constructing additional pages ... that clearly explained the broad concepts related to ecology and consequently the species catalogued on the CD.”[195] The students presented these concept pages to the entire assembly of 85 peers and together they edited and selected the concept pages that were to be included in the field guide. Students then “produced a master CD which was duplicated, labeled and packaged by students.”[196] The product of the

[190] Grant, D. (2002) “Fading Footprints” (p. 6), SEED. <http://king.portlandschools.org/documents/fprints/begin.html>
[191] Ibid., p. 5.
[192] Ibid., p. 6.
[193] Ibid., p. 6.
[194] Ibid., p. 5.
[195] Ibid., p. 6.
[196] Ibid., p. 6.

students' learning, a field guide, is "a text they will not quickly forget because they wrote and published it – for themselves and for [their] community."[197]

> What the students ultimately constructed through the production of the CD was the text of the entire ecology curriculum in their own words, images, knowledge links, etc.[198]
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> ...
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> What more accurate representation of their learning could the students have produced?[199]

5.5 The Assimilation-Accommodation Dimension

Two kinds of educational computing have been illustrated. Each has its own sphere of applicability. A different mental model of technology underlies each mode of use. It is said that mental models can be analyzed along an assimilation-accommodation continuum.[200] A major distinction between the two models of educational computing is their relative "position on a dimension of assimilation-accommodation."[201]

The Fading Footprints example is at the assimilatory end which frames educational computing "in terms of its relationships to other systems already

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[197] Grant, D. (2002) "Fading Footprints" (p. 5), SEED. <http://king.portlandschools.org/documents/fprints/begin.html>

[198] Ibid., p. 5.

[199] Ibid., p. 7.

[200] Young, R.M. (1983) "Surrogates and Mappings: Two Kinds of Conceptual Models for Interactive Devices" (p. 51) in D. Gentner and A.L. Stevens, eds., *Mental Models* (pp. 35-52). Hillsdale, NJ: Lawrence Erlbaum Associates.

[201] Ibid.

familiar to the user"[202] such as the activity of researching and publishing information. The Apple Vivarium example is at the accommodatory end where "the emphasis is more on an understanding of the device in its own right."[203] The Apple Vivarium activity takes as its starting point the programming capability of the machine, a functionality unique to the computer. In contrast, the Fading Footprints activity is organized around seeing the computer as a tool for carrying out a familiar activity and enhancing its quality.

The Fading Footprints activity is more representative of the currently dominant model of technology use in education. It emphasizes the information technology and multimedia capabilities of the computer. Moreover, it is focused on assimilating technology use into pre-existing educational activities with an aim to improve them. This is by no means a poor use of technology. However, the pervasive conception of computers as information technology and multimedia machines may be evidence for what Papert calls "assimilation blindness" on the part of the education community.[204]

Papert uses the phrase "assimilation blindness" to refer to a person's or an institution's inability to consider ideas that fall outside of the familiar.[205] Casting computer technology in the paradigmatically familiar role of information technology and multimedia machine, in the tradition of such

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[202] Young, R.M. (1983) "Surrogates and Mappings: Two Kinds of Conceptual Models for Interactive Devices" in D. Gentner and A.L. Stevens, eds., *Mental Models* (pp. 35-52). Hillsdale, NJ: Lawrence Erlbaum Associates.
[203] Ibid.
[204] Papert, S. (1997) "Why School Reform is Impossible," *The Journal of the Learning Sciences*, 6(4), pp. 417-427
[205] Ibid.

"electronic pedagogy"[206] devices like film, radio, and television, may for a time facilitate the computer's entry into the classroom and its widespread use, but it may also engender and reinforce an asssimilation blindness to other strategies for educational technology use, especially those that aim to take better advantage of functionalities unique to the computer.

[206] Papert, S. (1997) "Why School Reform is Impossible," *The Journal of the Learning Sciences*, 6(4), pp. 417-427

6 AN ALTERNATIVE MODEL FOR EDUCATIONAL TECHNOLOGY

6.1 Computers as Programming Environments

The following sections discuss an alternative mental model for thinking about the educational use of computers. This mental model of computers as programming environments derives from ideas articulated in Papert's *Mindstorms: Children, Computers, and Powerful Ideas*, published in 1980. An assessment of the relative merits of Papert's mental model of computers as programming environments is not at issue here. This mental model is studied here only as one of many possible alternatives to the currently pervasive mental model of computers as information technology and multimedia machines.

In *Mindstorms*, Papert envisioned "a particular way of using computers"[207] and a transformed educational model that is "dependent on a computer-rich future."[208] To clarify, Papert stated his vision for computers and children as follows:

> In my vision, *the child programs the computer* and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes

[207] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 18). New York: Basic Books.
[208] Ibid., p. 18.

> an intimate contact with some of the deepest ideas from science, from mathematics, and from the art of intellectual model building.[209]

Papert's key assertion in *Mindstorms* is that digital technology can change how children relate to different domains of knowledge, and consequently challenge "current beliefs about who can understand what and at what age."[210] Papert argues that technology in education is not simply about the mastery of machines, but at its best is about the mastery of formal systems. According to Papert, the computer can have a special role in providing a more accessible entry to formal systems.

In *Mindstorms*, computer access is presented as a necessary provision for a generation of students to be introduced to the activity of programming the computer. Programming, in turn, is seen as a means to create "microworlds" that provide children opportunities to play with "powerful ideas", to engage with formal ideas in ways that leverage children's existing intuitive theories and enable children to form relationships with formal domains to promote further growth of intuitive knowledge. Papert's intention is that technology presence in children's lives can initialize this chain of events and force an open discussion on how "certain uses of very powerful computational technology and computational ideas can provide children with new possibilities for learning, thinking, and growing emotionally as well as cognitively."[211]

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[209] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 5). New York: Basic Books.
[210] Ibid., p. 4.
[211] Ibid., pp. 17-18.

While technology may be central to the discussion in *Mindstorms*, Papert's case for technology presence in children's education is only a starting point for a complex discussion involving the value of intuitive theories, the process of rethinking the educational curriculum, and the impact of computational thinking on educational culture.

6.1.1 Access to Programming

In *Mindstorms*, Papert encouraged the reader to "look at programming as a source of descriptive devices."[212] Papert predicted that "in a computer-rich world, computer languages that simultaneously provide a means of control over the computer and offer new and powerful descriptive languages for thinking will ... have a particular effect on our language for describing ourselves and our learning."[213] It was Papert's goal to introduce children and their teachers to the experience of programming the computer. His "research agenda on computers and education"[214] focused on creating "environments in which children can learn to communicate with computers."[215] Papert was motivated to show "that children can learn to use computers in a masterful way, and that learning to use computers can change the way they learn everything else."[216]

LOGO was the computer language that Papert invented and used to demonstrate that "children can learn to program."[217] Papert also worked to

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[212] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 98). New York: Basic Books.
[213] Ibid., p. 98.
[214] Ibid., p. 8.
[215] Ibid., p. 8.
[216] Ibid., p. 8.
[217] Ibid., p. 13.

demonstrate that in the activity of programming, "the child is learning how to exercise control over an exceptionally rich and sophisticated 'microworld'."[218] LOGO was specially "designed to provide very early and easy entry routes into programming for beginners with no prior mathematical knowledge."[219] In LOGO, "the idea of programming is introduced through the metaphor of teaching the Turtle a new word."[220] The Turtle is a programmable object on the computer screen and "children often begin their programming experience by programming the Turtle to respond to new commands invented by the child."[221] "Children working with [the Turtle] are learning a language for talking about shapes and fluxes of shapes, about velocities and rates of change, about processes and procedures."[222]

LOGO was developed under "the assumption that children would have access to personal computers that could support a powerful programming language."[223] However, it was not Papert's intention to promote LOGO as "the definitive language"[224] for children to learn how to program. LOGO was invented to serve as a model for what might be possible – a model for pursuing possibilities in the employment of computation as a rich medium for children's construction of tangible artifacts and of personally meaningful knowledge. In summary, Papert advocated that students "use programming

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[218] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 12). New York: Basic Books.
[219] Ibid., p. 217.
[220] Ibid., p. 12.
[221] Ibid., p. 12.
[222] Ibid., p. 13.
[223] Turkle, S. (1984) *The Second Self: Computers and the Human Spirit* (p. 339). New York: Simon and Schuster.
[224] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 217). New York: Basic Books.

as an expressive medium to study other topics rather than as a skill to be learned for the sake of learning it."[225]

6.1.2 Creating Microworlds

In the *Mindstorms* vision, programming is a critical piece of the use of computers in education because microworlds and the computational objects embedded within them stand "between the world of physical objects and the world of abstract ideas."[226] In Papert's vision, the computer acts as a transitional object to mediate between children's intuitive theories and formal domains of knowledge. Papert coined the term "Mathland" to represent a class of microworlds, a model of computer use in education that explores the idea of both formal mathematics and computer programming through intuitive engagement.

According to Papert, a computer-based Mathland offers "a Piagetian learning path" into mathematics.[227] Put simply, "Piagetian learning" is "learning without being taught."[228]

> In [*Mindstorms*] the Mathland metaphor will be used to question deeply ingrained assumptions about human abilities. It is generally assumed that children cannot learn formal geometry until well into their school years and that

[225] Papert, S., "Introduction to the Second Edition" (p. xvii) in Papert, S. (1993) *Mindstorms: Children, Computers, and Powerful Ideas, Second Edition*. New York: Basic Books.
[226] Turkle, S. (1984) *The Second Self: Computers and the Human Spirit* (p. 106). New York: Simon and Schuster.
[227] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 123). New York: Basic Books.
[228] Ibid., p. 7.

most cannot learn it too well even then.[229]

Papert asked the reader to consider why some learning – for instance, the learning of mathematics – does not seem to happen "without deliberately imposed formal instruction."[230] Papert makes a distinction between mathematics, "a vast domain of inquiry whose beauty is rarely suspected by most nonmathematicians" and "something else" which he termed "school math."[231] School math, "the kind of mathematics foisted on children in schools," is "not meaningful, fun, or even very useful."[232] The conjecture he put forward is that "much of what we now see as too 'formal' or 'too mathematical' will be learned just as easily when children grow up in the computer-rich world of the very near future."[233] This is because for Papert, "the critical factor [is] the relative poverty of the culture in those materials that would make the concept simple and concrete."[234] It is Papert's belief that the computer uniquely enables the construction of such materials for "Piagetian learning."

In *Mindstorms*, Papert describes a microworld that engages formally with mathematics, in part because he is a mathematician, but also because, culturally, math is often seen as "having rigid limitations" and, practically, "it is not uncommon for intelligent adults" to engage in only "the most rudimentary mathematics."[235] Papert is interested in enabling an intuitive relationship with mathematics and feels that the absence of this relationship

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229 Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 6). New York: Basic Books.
230 Ibid., p. 7.
231 Ibid., p. 51.
232 Ibid., p. 50.
233 Ibid., p. 7.
234 Ibid., p. 7.
235 Ibid., p. 39.

can “limit people’s lives.”[236] His critique of traditional approaches to the teaching of mathematics in schools is that they are “paradigmatic of dissociated learning,”[237] where “material is treated as meaningless.”[238] Additionally, “everything is set up for children to attribute their first unsuccessful or unpleasant learning experiences to their own disabilities,” leading to the frequent assessment that they “can’t do math.”[239] To illustrate the limitations of traditional approaches to mathematics education, Papert asked us to imagine the application of “school math”[240] to dance instruction:

> Imagine that children were forced to spend an hour a day drawing dance steps on squared paper and had to pass tests in these “dance facts” before they were allowed to dance physically ... Would we say that those who made it to the dance floor and music had the greatest “aptitude for dance”? In my view it is no more appropriate to draw conclusions about mathematical aptitude from children’s unwillingness to spend many hundreds of hours doing sums.[241]

“The Mathland concept shows how to use computers as vehicles to escape”[242] this established “one route”[243] to learning mathematics and to provide a

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236 Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 42). New York: Basic Books.
237 Ibid., p. 48.
238 Ibid., p. 47.
239 Ibid., p. 43.
240 Ibid., p. 46.
241 Ibid., p. 43.
242 Ibid., p. 45.
243 Ibid., p. 46.

"sense of purpose"[244] and "points of contact between what is most fundamental and engaging in mathematics."[245]

The "simple thought experiment of imagining Mathland"[246] is of value not only in re-thinking education in mathematics, but also education at large. As Papert points out, "mathematics is certainly not the only example of dissociated learning"[247]; "Mathland is the first step in a larger argument about how the computer presence can change not only the way we teach children mathematics, but, much more fundamentally, the way in which our culture as a whole thinks about knowledge and learning."[248]

In *Mindstorms*, Turtle geometry is a representative example of a microworld in the Mathland theme:

> [The Turtle has a] special ability to serve as a first representative of formal mathematics for a child. Children can *identify* with the Turtle and are thus able to bring their knowledge about their bodies and how they move into the work of learning formal geometry.[249]
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> …
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> The Turtle establishes a bridge. It serves as a common medium in which can be recast the shared elements of body geometry and formal geometry.[250]

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[244] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 45). New York: Basic Books.
[245] Ibid., p. 47.
[246] Ibid., p. 43.
[247] Ibid., p. 47.
[248] Ibid., p. 39.
[249] Ibid., p. 56.
[250] Ibid., p. 183.

> …
>
> Turtle geometry is a different style of doing geometry, just as Euclid's axiomatic style and Descartes's analytic style are different from one another. Euclid's is a logical style. Descartes's is an algebraic style. Turtle geometry is a *computational* style of geometry.[251]

Other Turtle microworlds have also been created. Outside of the Mathland model, Resnick's Starlogo is an example of a microworld in which ideas surrounding group behavior and complexity are bridged through the use of a number of Turtles which operate in parallel and draw upon children's understanding of the Turtle, its relation to its Turtle neighbors and the formal commands that it receives from the child programmer.

6.1.3 Mobilizing Powerful Ideas

Papert asserted that a microworld creates an environment that facilitates interaction with and understanding of a powerful idea or a set of powerful ideas: "The design of the microworld makes it a 'growing place' for a specific species of powerful ideas."[252] He referred to microworlds as "incubators for powerful ideas."[253]

In *Mindstorms*, Papert described how a key mathematical concept, the idea of a variable, can be introduced to children as a powerful idea in the context of programming in the LOGO environment:

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[251] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 55). New York: Basic Books.
[252] Ibid., p. 125.
[253] Ibid., p. 126.

> In the LOGO environment new ideas are often acquired as a means of satisfying a personal need to do something one could not do before. In a traditional school setting, the beginning student encounters the notion of variable in little problems such as:
>
> 5 + X = 8. What is X?
>
> Few children see this as a personally relevant problem, and even fewer experience the method of solution as a source of power. They are right. In the context of their lives, they can't do much with it. In the LOGO encounter, the situation is very much different. Here the child has a personal need: To [program the Turtle to draw] a spiral. In this context the idea of a variable is a source of personal power, power to do something desired but inaccessible without this idea. Of course, many children who encounter the notion of variable in a traditional setting do learn to use it effectively. But it seldom conveys a sense of "mathpower," not even to the mathematically best and brightest. And this is the point of greatest contrast between an encounter with the idea of variables in the traditional school and in the LOGO environment. In LOGO, the concept empowers the child, and the child experiences what it is like for mathematics to enable whole cultures to do what no one could do before.[254]

Papert used the example of children appropriating the concept of using variables in order to program the Turtle to draw a spiral to demonstrate "the

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[254] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 74). New York: Basic Books.

power principle": Powerful ideas "empower the learner to perform personally meaningful projects that could not be done without it."[255] Papert's argument is that while "the concept of symbolic naming through a variable" is "one of the most powerful mathematical ideas ever invented,"[256] it is often introduced to students in traditional schooling in forms that are not concrete or useful. Other examples of powerful ideas in Turtle geometry include "the use of numbers to measure angles,"[257] "recursion,"[258] and concepts from calculus such as "the concept of line integral"[259] and "the notion of differential equation."[260] In "an explorable and manipulable environment"[261] like LOGO, these ideas become powerful because "the child can actually use it"[262] and "play with it."[263] "Each new idea in Turtle geometry opened new possibilities for action and could therefore be experienced as a source of personal power."[264]

In *Mindstorms*, Papert set out to develop "an epistemology of powerful ideas."[265] He advanced "the image of a domain of knowledge as a community of powerful ideas."[266] He asserted that computers can change our perception of what a domain of knowledge (like mathematics) is about and "of what powerful ideas are most important in it."[267] In this context, Turtle microworlds were created to demonstrate "the idea ... that early experience

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[255] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 54). New York: Basic Books.
[256] Ibid., p. 69.
[257] Ibid., p. 68.
[258] Ibid., p. 71.
[259] Ibid., p. 220.
[260] Ibid., p. 221.
[261] Ibid., p. 129.
[262] Ibid., p. 76.
[263] Ibid., p. 129.
[264] Ibid., p. 129.
[265] Ibid., p. 137.
[266] Ibid., p. 137.
[267] Ibid., p. 151.

with Turtles is a good way to 'get to know' what it is like to learn a formal subject by 'getting to know' its powerful ideas."[268] Papert summarized his belief in the power of powerful ideas as follows:

> By growing up with ... powerful [ideas] one comes to appreciate how certain ideas can be used as tools to think with over a lifetime. One learns to enjoy and to respect the power of powerful ideas. One learns that the most powerful idea of all is the idea of powerful ideas.[269]

6.1.4 Nurturing Intuitive Knowledge

Papert was "interested in how a powerful idea is made part of intuitive thinking."[270] He proposed that "work with the Turtle provides specific intuitive models for complex mathematical concepts most children find difficult."[271] As an example, he presented how a program that makes the Turtle draw a circle is "an intuitive analog of the differential equation."[272]

> For a student, drawing a Turtle circle is more than a "common sense" way of drawing circles. It places the child in contact with a cluster of ideas that lie at the heart of calculus. This fact may be invisible to many readers whose only encounter with calculus was a high school or college course where "calculus" was equated with certain formal

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[268] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 138). New York: Basic Books.
[269] Ibid., p. 76.
[270] Ibid., p. 154.
[271] Ibid., p. 68.
[272] Ibid., p. 66.

> manipulations of symbols. The child [drawing a Turtle circle] was not learning about the formalism of calculus ... but about its use and its meaning. In fact the Turtle circle program leads to an alternative formalism for what is traditionally called a "differential equation" and is a powerful carrier of the ideas behind the differential.[273]

A related example is the activity of "programming a Turtle to circumnavigate an object."[274] For Papert, these programming activities capture "an essential core of the notion of differential equation"[275] and facilitate understanding of this key mathematical concept:

> I have seen elementary school children who understand clearly why differential equations are the natural form of laws of motion. Here we see another dramatic pedagogic reversal: The power of the differential equation is understood before the analytic formalism of calculus.[276]

In this way, "Turtle geometry opens the door to an intuitive grasp of calculus, physics, and mathematical modeling as it is used in the biological and social sciences."[277] The Turtle, a computational object, can aid children in developing intuitive understanding of the differential equation because it is

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[273] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 66). New York: Basic Books.
[274] Ibid., p. 221.
[275] Ibid., p. 221.
[276] Ibid., p. 221.
[277] Ibid., p. 68.

"a reconstruction in intuitive computational form of the qualitative core of this mathematical structure."[278]

Papert urged his reader to recognize "the existence of these informally learned, powerful intuitive ideas" because "by recognizing their existence we should be able to create conditions that will foster their development."[279] Papert's research agenda in *Mindstorms* was primarily concerned with imagining and creating computational learning environments that would facilitate the acquisition of these powerful intuitive ideas and "remove obstacles that block them in many traditional learning environments."[280] According to Papert, "we need to improve our intuition, to debug it, but the pressure on us is to abandon intuition and rely on equations instead."[281] "[The student] needs to know how to work on his intuitions in order to change them,"[282] Papert asserted; "But what can children do to confront *their* intuitions?"[283] Papert believes that children already confront their intuitions and debug them, and with the use of the computer, "we can provide materials to help them do it better."[284]

> I see the computer as helping in two ways. First, [programming] the computer allows, or obliges, the child to externalize intuitive expectations. When the intuition is translated into a program it becomes more obtrusive and more accessible to reflection. Second, computational ideas

[278] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 68). New York: Basic Books.
[279] Ibid., p. 144.
[280] Ibid., p. 144.
[281] Ibid., p. 144.
[282] Ibid., p. 144.
[283] Ibid., p. 145.
[284] Ibid., p. 145.

can be taken up as materials for the work of remodeling intuitive knowledge.[285]

As an example of how computational ideas can help remodel intuitive thinking and thus "bridge the gap between formal knowledge and intuitive understanding,"[286] Papert points to the Turtle model of drawing a circle. Programming the Turtle to "take a little step forward" and then "turn a little" and to "keep doing it"[287] will draw a circle on the computer screen and make apparent "the equivalence between polygonal representation and circle" or the idea of seeing a circle as a polygon with many, many sides.[288]

In *Mindstorms,* Papert put forward the proposition that creating microworlds to play with and explore powerful ideas engages children's existing intuitive knowledge and facilitates the development of new intuitive knowledge. This is especially important in domains like mathematics or physics which tend to be inaccessible to children because of the traditional language of formal description. Papert places a high value on both leveraging and nurturing intuition. The story of a third-grader named Ronnie aptly illustrates how engaging children's intuition can provide "a point of entry"[289] for children to approach formalisms that they otherwise might not be interested in or recognize a purpose in learning.

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[285] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 145). New York: Basic Books.
[286] Ibid., p. 145.
[287] Ibid., p. 58.
[288] Ibid., pp. 149-150.
[289] Turkle, S. (1984) *The Second Self: Computers and the Human Spirit* (p. 126). New York: Simon and Schuster.

Ronnie is introduced as a child who “has trouble with mathematics, with grammar, with spelling, with everything that smacks of being a formal system.”[290] The story then goes on to describe Ronnie’s process of working to program in LOGO a dance pattern for different colored balls:

> Ronnie has never heard the term “variable,” and it would be nearly impossible to explain it to him. But he has experimented [in the LOGO microworld] enough to understand that to get the perfect dance he has to change the speed at which the balls fly out and the time of their flight before they return. So, without having the words to express precisely what he does, Ronnie works with two variables in order to control the spatial and temporal pattern of the explosion ... Ronnie’s mode of interaction with this program consists of trying different things, watching how they work out, dancing to the new rhythms, and then stepping back to make further attempts to make the patterns more satisfying by changing one or the other of the variables ... In the course of a long afternoon, Ronnie has learned how to work a little formal system, one that some people might learn in the section of the algebra curriculum called “rates, times, and distances.” But Ronnie might never have gotten there, for the standard route to algebra lies through many hours of a different kind of activity: sitting still at a desk, filling numbers into squares,

[290] Turkle, S. (1984) *The Second Self: Computers and the Human Spirit* (p. 120). New York: Simon and Schuster.

> manipulating equations on paper.[291]

Ronnie's story demonstrates how engaging a child's intuition enables that child to learn and be enriched by material that otherwise remains practically inaccessible:

> Children like ... Ronnie tend to be afraid of technical objects and develop negative relationships with science and mathematics. As they grow older, they become more defensive. An early computer experience might make a difference. Unlike arithmetic and school math drill, the computer ... provides an expressive medium ... Whether or not they go on to excel in computational, mathematical, or scientific studies is an open question. But they have a point of entry.[292]

Papert acknowledges that "for most children in contemporary societies there may indeed be only one route into 'advanced' mathematics, the route via school math."[293] Consequently, *Mindstorms* "is an argument that alternate routes do exist" and that "we should seek out [these] routes":[294]

> Our education culture gives mathematics learners scarce resources for making sense of what they are learning. As a result our children are forced to follow the very worst

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[291] Turkle, S. (1984) *The Second Self: Computers and the Human Spirit* (p. 121). New York: Simon and Schuster.
[292] Ibid., p. 126.
[293] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 46). New York: Basic Books.
[294] Ibid., p. 46.

> model for learning mathematics. This is the model of rote learning, where material is treated as meaningless; it is a dissociated model ... Before we had computers there were very few good points of contact between what is most fundamental and engaging in mathematics and anything firmly planted in everyday life. But the computer – a mathematics-speaking being in the midst of the everyday life of the home, school, and workplace – is able to provide such links. The challenge to education is to find ways to exploit them.[295]

Engaging intuitive knowledge through microworlds is a resource that was unavailable before, a way to move beyond the existing mode of education. Microworlds immerse children in powerful ideas, engaging their existing intuitions to make what they are learning “make sense”,[296] to develop new intuitions that can similarly be leveraged in the future. “The problem of making mathematics ‘make sense’ to the learner touches on the more general problem of making a language of ‘formal description’ make sense.”[297] In summary, the *Mindstorms* vision is not simply about engaging intuitions in mathematics, but is about engaging intuitions in many and any area of formal description.

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[295] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 47). New York: Basic Books.
[296] Ibid., p. 48.
[297] Ibid., p. 48.

6.1.5 Recasting the Curriculum

In *Mindstorms*, Papert calls for a "reconceptualization"[298] of the curriculum – "the recasting of knowledge into new forms"[299] – a process which involves more than "a mere change in pedagogy or technology."[300]

> The traditional approach accepts school math as a given entity and struggles to find ways to teach it. Some educators use computers for this purpose ... In Turtle geometry, the computer has a totally different use. There the computer is used as a mathematically expressive medium, one that frees us to design personally meaningful and intellectually coherent and easily learnable mathematical topics for children. Instead of posing the educational problem as "how to teach the existing school math," we pose it as "reconstructing mathematics," or more generally, as reconstructing knowledge in such a way that no great effort is needed to teach it.[301]

Papert presented "microworlds as a response to a pedagogical problem" – "the problem of prerequisites."[302]

> Most physics curricula are similar to the math curriculum in that they force the learner into dissociated learning

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298 Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 185). New York: Basic Books.
299 Ibid., p. 184.
300 Ibid., p. 185.
301 Ibid., p. 53.
302 Ibid., p. 132.

> patterns and defer the "interesting" material past the point where most students can remain motivated enough to learn it. The powerful ideas and the intellectual aesthetic of physics is lost in the perpetual learning of "prerequisites."[303]

Papert used the topic of Newtonian laws of motion as an example of "a topic usually considered paradigmatic of the kind of knowledge that can only be reached by a long, formalized learning path."[304] This is because "until the advent of the computer, there were only very poor environmental materials for the construction of a Newtonian world."[305] Consequently, "students trying to develop Newtonian thinking about motion" have to do so "in the absence of direct and physical experiences of Newtonian motion."[306] Papert postulated that a computer microworld could help give students an intuitive, direct experience with Newtonian motion:

> In the absence of direct and physical experiences of Newtonian motion, the schools are forced to give the student indirect and highly mathematical experiences of Newtonian objects. There movement is learned by manipulating equations rather than by manipulating the objects themselves. The experience, lacking immediacy, is slow to change the student's intuitions. And it itself requires other formal prerequisites. The student must first

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303 Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 122). New York: Basic Books.
304 Ibid., p. 123.
305 Ibid., p. 129.
306 Ibid., p. 123.

> learn how to work with equations before using them to model a Newtonian world. The simplest way in which our computer microworld might help is by putting students in a simulated world where they have direct access to Newtonian motion. This can be done when they are young. It need not wait for their mastery of equations. Quite the contrary: Instead of making students wait for equations, it can motivate and facilitate their acquisition of equational skills by providing an intuitively well understood context for their use.[307]

Papert asserted that "students who know Turtle geometry" are "in a position to formulate in a qualitative and intuitive form the substance of Newton's first two laws" and that "we can design other Turtle microworlds in which the laws of motion move toward a closer approximation of the Newtonian situation."[308]

An important part of the vision of *Mindstorms* is to use the force of technology to recast the educational curriculum. If Papert's understanding of mathematics is accurate, if "our children are forced to follow the very worst model for learning mathematics" and if the computer is able to provide "good points of contact between what is most fundamental and engaging in mathematics,"[309] then certainly the mathematics curriculum should be reconsidered. Furthermore, if Papert's understanding is correct in that

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[307] Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (pp. 123-124). New York: Basic Books.
[308] Ibid., p. 127.
[309] Ibid., p. 47.

"mathematics is ... not the only example of dissociated learning,"[310] then the re-evaluation of the educational curriculum as a whole might be opened.

> In [*Mindstorms*] we have seen complex interactions between new technologies and the recasting of the subject matters. When we discussed the use of the computer to facilitate learning Newton's laws of motion, we did not attempt to "computerize" the equations as they are found in a classical textbook. We developed a new conceptual framework for thinking about motion. For example, the concept of Turtle enabled us to formulate a qualitative component of Newtonian physics. The resulting reconceptualizing would be valid without a computer; its relation to the computer is not at all reductionist. But it is able to take advantage of the computer in ways in which other conceptualizations of physics could not ... Thus, the whole process involves a dialectical interaction between new technologies and new ways of doing physics.[311]

Papert urged the reader to look at "the complete picture" of the *Mindstorms* vision and "recognize a dialectical interaction between the content, the pedagogy, and the technology."[312]

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310 Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (p. 47). New York: Basic Books.
311 Ibid., p. 184.
312 Ibid., p. 185.

6.1.6 Exploring Computational Thinking

Mindstorms "grew out of a project designed to explore this concept" of "seeing ideas from computer science" as "instruments of change that might alter, and possibly improve, the way people learn and think."[313] This is to be achieved by "giving children access to the best of computer science including some of its best technology and some of its best ideas."[314]

The powerful ideas surfaced by Turtle geometry and the "best ideas"[315] of computer science include "the concept of symbolic naming through a variable,"[316] "recursion,"[317] and ideas formalized in calculus such as the "line integral"[318] and the "differential equation."[319] Such ideas are not bound up only in formal mathematics, but are instrumental in engineering and design, the sciences and even more broadly in our collective understanding of the natural world.

It is Papert's hope that through computer science and the activity of programming and playing with powerful ideas in microworlds, that the acquisition of intuitive knowledge about formal domains of study would lead people to ask fundamental questions like: "What *is* physics? And what is the potential influence of computation on understanding it?"[320]

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313 Papert, S. (1980) *Mindstorms: Children, Computers, and Powerful Ideas* (pp. 208-209). New York: Basic Books.
314 Ibid., p. 209.
315 Ibid., p. 209.
316 Ibid., p. 69.
317 Ibid., p. 71.
318 Ibid., p. 220.
319 Ibid., p. 221.
320 Ibid., p. 140.

6.2 Examining Strategic Choices

Of a number of possibilities, two mental models surrounding the use of educational technology have been presented in this dissertation. The first is a widely espoused mental model which frames computer technology in terms of Internet and multimedia applications and seeks to assimilate computer technology's information and presentation capabilities with the existing educational structure, curriculum, pedagogical approaches, and expectations. This prevalent mental model continues to drive educational technology adoption in the United States. As one possible alternative, the mental model espoused by Papert and Kay views computer technology medium in terms of its programmability. This alternative model identifies computer presence with the unique opportunity to reshape the current curriculum and introduce innovative ways to represent subject matter through dynamic simulations. These two mental models differ in their underlying assumptions and as a result have divergent expectations and aims regarding technology adoption in schools. The following table contrasts facets of these two mental models.

Computers as Information Technology and Multimedia Machines	Computers as Programming Environments
Access to the Internet Multimedia Authoring Studying Up-to-Date Information Acquiring Scholastic Knowledge Integrating Technology into the Curriculum Developing Computer Literacy	Access to Programming Creating Microworlds Mobilizing Powerful Ideas Nurturing Intuitive Knowledge Recasting the Curriculum Exploring Computational Thinking

"The point ... is not to find the right 'strategy,' but to bring to the surface the assumptions underlying each strategy, and to give people the chance to experience the potential impacts of their proposed strategic choices in a safe environment."[321] It is my sincere belief that:

> Hope for the future lies in growing awareness and willingness to experiment from many quarters and many philosophical perspectives. No one person has to come up with all the answers; indeed, that may be exactly what is not needed.[322]

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[321] Senge, P. et al (1999) *The Dance of Change: The Challenges of Sustaining Momentum in Learning Organizations* (p. 499). New York: Doubleday.
[322] Senge, P. et al (2000) *Schools that Learn: A Fifth Discipline Fieldbook for Educators, Parents, and Everyone Who Cares About Education* (p. 52). New York: Doubleday.

7 CONCLUSION

7.1 Summary of Findings

Existing studies of computers and education have failed to take into account the relevance and importance of tacit assumptions and taken-for-granted expectations that underlie educational technology practices. A major premise of this dissertation is that it is these taken-for-granted interpretations of technology that most significantly influence how technology is being used in the sphere of education. It is thus analytically useful to examine technology use in education by investigating the assumptions on which currently pervasive educational technology practices are built.

Based on established research in cognitive science and organizational learning, I employ the theoretical concept of mental models to study current educational technology practices. An examination of the academic and popular literature revealed key elements of the prevailing mental model of technology in education, which I call the mental model of computers as information technology and multimedia machines. Within the education community, this mental model embodies a shared conceptualization regarding the utility of technology in improving the education process. This mental model is focused on Internet access and the multimedia authoring capacity of the computer. Computer technology is viewed as a means to provide students and teachers with Internet connectivity and access to extensive, up-to-date, “better than textbook” information. The computer’s multimedia authoring capacity can then be utilized to synthesize the wealth of information culled from Internet sources into presentations with integrated text, graphics, sound, and video. According to this mental model, information technology and multimedia authoring applications of the computer, taken together, provide an effective strategy to motivate and educate students. Integrating technology use with the school's curriculum objectives is said to facilitate student engagement and independent exploration of academic content and, at the same time, equip students with valuable technology know-how for future employment.

I then investigated how the mental model of computers as information technology and multimedia machines organizes thinking about technology use and education within a large-scale initiative to implement wirelessly connected, one-to-one computing in public schools. The technology initiative studied is the Maine Learning Technology Initiative (MLTI), in which over 30,000 laptop computers were distributed to 7th- and 8th-grade students and teachers in 2002 and 2003. I found that MLTI participants did strongly draw on the mental model of computers as information technology and multimedia machines to use the newly deployed technology. This mental model became widely shared and quickly taken for granted by participants, as evident in their pattern of technology use. By the end of the initiative's first year, MLTI teachers and students were using the laptop computers in strikingly similar ways: that is, as a means to access information on the Internet and as a tool for creating multimedia projects in the forms of slideshows, websites, and to a lesser extent, digital movies.

In my review of institutional messages to Maine teachers, which included official communications from the Maine Department of Education and various documents distributed at teacher training sessions, I found that these institutional voices also collectively reinforced the use of the laptop computers in accordance with the mental model of computers as information technology and multimedia machines. By continuing to draw on this mental model to guide actions around the new technology during the first years of the MLTI, the community reaffirmed the validity of the mental model and hence reinforced a particular interpretation and use of the laptop computers.

One-to-one computer access has become a reality for students and teachers in many school districts and states and the trend is quickly gaining support throughout the country. The MLTI is but one example of numerous one-to-one computing initiatives, in which Internet- and multimedia-centered uses of computer technology have become a taken-for-granted part of normal operations. In the MLTI, the mental model of computers as information technology and multimedia machines became well-entrenched during the first years of technology implementation, to the extent that individual efforts to explore and experiment outside of the Internet and multimedia paradigm were shunned by the community.

7.2 The Need to Examine Current Strategy

After one and a half years of using the laptop computers in class, an MLTI teacher said to me in an interview:

> I'm trying to figure out what else there is to do with these laptops. It's getting hard to keep the ball rolling. I feel like the excitement has worn off. New websites used to be exciting ... but now things are more identified. We know how to use all these applications now ... and my kids still

> enjoy doing projects like slideshows and iMovies ... but the joy of discovery isn't there anymore. I'm having a hard time imagining what else to do. It just feels like the opportunities are not endless after all.

"I'm having a hard time imagining" – such is the powerful and pervasive influence of unexamined mental models, especially those that have become widely shared within a community of practice. Echoing Orlikowski's findings in her study of a business organization's Lotus Notes implementation, the established mental model of computers as information technology and multimedia machines appears to be a constraining factor on what technological possibilities are recognized and pursued.

Organizational learning theorist, Edgar Schein, points out that success is an effective contributor in facilitating assumptions and routines to become unexamined, reinforced, and eventually entrenched: "If the organization is successful ... [the assumptions on which it operates] come to be shared [among members], seen as correct, and eventually taken for granted."[323] In order for an organization to continue to evolve its practice, its members must work on developing "the openness needed to unearth [limitations] in [their] present ways of seeing the world."[324]

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[323] Schein, E.H. (1999) *The Corporate Culture Survival Guide: Sense and Nonsense About Culture Change* (p. 91). San Francisco, CA: John Wiley & Sons, Inc.

[324] Senge, P.M. (1994) *The Fifth Discipline: The Art & Practice of the Learning Organization* (p. 12). New York: Currency Doubleday.

“We all hold certain taken-for-granted assumptions”[325] and we can work to “expose and test the assumptions behind [our] current strategy”[326] The first and most important step, of course, is to recognize that taken-for-granted assumptions or mental models exist. Because it is not until we understand more deeply the core assumptions upon which we presently base our thoughts and actions – not until we have examined our established mental models – that we can come to recognize limitations of our current thinking.[327] In other words, “we must first examine the assumptions of our present models” in order to evolve new ones.[328]

Using the concept of mental models as an analytical lens to study technology practices in education holds promise in serving to foster discussion, reflection, and reorientation within the education community. Future empirical work is needed to track established and emerging mental models in the education community over time, as well as to assess the extent of the influence of mental models on technology use in different education change efforts. Identifying the means through which mental models around technology become shared within a community would also be a rich area for future study.

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325 Senge, P.M. et al (1999) *The Dance of Change: The Challenges of Sustaining Momentum in Learning Organizations* (p. 47). New York: Doubleday.
326 Ibid., p. 498.
327 Senge, P.M. et al (2000) *Schools that Learn: A Fifth Discipline Fieldbook for Educators, Parents, and Everyone Who Cares About Education*. New York: Doubleday.
328 Costa, A.L. and Kallick, B. (199?) “Shifting the Paradigm: Giving Up Old Mental Models,” in Costa, A.L., Kallick, B. (1995) *Assessment in the Learning Organization: Shifting the Paradigm*. Alexandria, VA: Association for Supervision and Curriculum Development (ASCD).

7.3 The State of Educational Use of Technology: A World of Limited Possibilities

The MLTI study highlights the pervasive influence and inherent inertia of an entrenched mental model. When users of technology draw upon a well-established and widely-shared mental model to drive their actions around technology, they will likely develop the tendency to view the particular mental model as *the* way technology is supposed to be used. Their technology experience and pattern of use as guided by the existing mental model, in turn, will serve to further reinforce the community's established mental model of technology use, institutionalizing a particular set of technology practices and routines. An entrenched mental model can have pervasive influence in limiting individual and collective capacities to consider and pursue possibilities outside of the established approach, or to even recognize the need for such pursuit. This happened during the first years of the MLTI effort, and is happening on a larger scale in the American education system as more and more computers become available to teachers and students in their classrooms.

The mental model of computers as information technology and multimedia machines is becoming a built-in part of the general educational technology discourse. The 2004 National Education Technology Plan[329] released by the U.S. Department of Education points to "Internet technology" as a force that is "changing the learning and teaching environment" within schools. The National Education Technology Plan report, which is titled *Toward A New Golden Age In American Education: How the Internet, the Law and Today's*

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[329] U.S. Department of Education, Office of Educational Technology (2004) *Toward A New Golden Age In American Education: How the Internet, the Law and Today's Students Are Revolutionizing Expectations.* Washington, D.C. <http://www.ed.gov/technology/plan>

Students Are Revolutionizing Expectations, portrays the current generation of American students as self-directed learners who prefer to "access subject information on the Internet, where it is more abundant, more accessible and more up-to-date."[330]

The conceptualization of computers as information technology and multimedia machines gives important insight into how educators view the role of technology with respect to education change. While the notion of "fundamentally transform[ing] education"[331] with technology by exploring its "endless possibilities for enriching the learning experience"[332] has always had a prominent place in American education discourse, as it is in the latest National Education Technology Plan, the mental model of educational technology inherent in the Plan's discussion of technology use in schools is more consistent with what is called first order technological change. First order change, by definition, is "change that occurs within an established mode of operating."[333] "By presuming the utility of established [mental models], first order change tacitly serves to reinforce present interpretations" and "results in incremental changes in current practices and relationships that do not require radically different assumptions, processes, or structures."[334]

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330 U.S. Department of Education, Office of Educational Technology (2004) *Toward A New Golden Age In American Education: How the Internet, the Law and Today's Students Are Revolutionizing Expectations.* Washington, D.C. <http://www.ed.gov/technology/plan>

331 Ibid.

332 Ibid.

333 Orlikowski, W. and Gash, D.C. (1991) *Changing Frames: Understanding Technological Change in Organizations* (p. 8). Cambridge, MA: Alfred P. Sloan School of Management, Massachusetts Institute of Technology.

334 Ibid., p. 11.

“We still do the same things. We just do it differently,” a 7th-grade student was quoted as saying while she worked on her social studies project, a multimedia presentation on ancient Greece.[335] “An incremental change is by definition not a major departure from the status quo”[336] and the use of computer technology to find information on the Internet and create multimedia presentations is a poignant example of this. In these uses, computer technology is “assimilated” to the concept of “electronic pedagogy”[337] along the same line as past classroom technologies like film, radio, and television. In first order change, technology plays a role that augments and reinforces established structures and processes. In the education realm, these established structures and processes revolve around the delivery of information as a vital act of education.

Moving beyond first order technological change would involve a deliberate act on the part of the education community to collectively rethink current practices, assumptions, values, and expectations and to be open to considering new frames of reference and ways of organizing. Fundamental, paradigmatic innovations will require the recognition of “the existence and role” of mental models and “an understanding of their influence” in shaping technology use.[338] Whether the established mental model of technology use in education will remain unexamined and exclusive, or whether other mental models will emerge depends on the ability of members of the education

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335 Sharp, D. (2003) “Maine School Gives Students Own Laptop,” Associated Press, June 11, 2003. <http://www.belleville.com/mld/belleville/news/6060160.htm>

336 Orlikowski, W. and Gash, D.C. (1991) *Changing Frames: Understanding Technological Change in Organizations* (p. 13). Cambridge, MA: Alfred P. Sloan School of Management, Massachusetts Institute of Technology.

337 Papert, S. (1997) “Why School Reform is Impossible,” *The Journal of the Learning Sciences*, 6(4), pp. 417-427

338 Orlikowski, W. and Gash, D.C. (1991) *Changing Frames: Understanding Technological Change in Organizations* (p. 19). Cambridge, MA: Alfred P. Sloan School of Management, Massachusetts Institute of Technology.

community to develop “the capacity to be aware of the perspectives from which they are operating.”[339] Building the capacity to critically examine the limits of the community’s current mode of operation would create conditions that allow for the emergence of new assumptions and meanings and decrease the likelihood that the community will become entrapped in “a paradigmatic state that may lose validity over time.”[340]

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[339] Orlikowski, W. and Gash, D.C. (1991) *Changing Frames: Understanding Technological Change in Organizations* (p. 9). Cambridge, MA: Alfred P. Sloan School of Management, Massachusetts Institute of Technology.
[340] Ibid., p. 8.

APPENDIX A: METHODS

A qualitative research design was chosen as the method for gaining an understanding of currently pervasive technology practices in education and the mental model underlying these practices.

Qualitative research plays an important and complementary role to other research approaches. Qualitative research takes an interpretive, naturalistic approach to its subject matter.[341] Qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings that people bring to them.[342]

Qualitative research is an appropriate research paradigm to use when the researcher has chosen to study an area that "has not been the primary focus for existing studies"[343] and thus the area of inquiry is not yet at the stage of having hypotheses to be investigated. "An important level of validation" for a qualitative study is the recognition from the reader's own experience of the dynamics described and analyzed in the study.[344] An important goal of a qualitative study is to define a new area of inquiry that can then be investigated more extensively in future studies.

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[341] Denzin, N.K. and Lincoln, Y.S., eds. (1994) *Handbook of Qualitative Research*. Thousand Oaks, CA: Sage Publications, Inc.

[342] Ibid.

[343] Davies, A. (2004) *Finding Proof of Learning in a One-to-One Computing Classroom (2002-2003): Report Submitted to Maine Learning Technology Initiative*, April 2004 (p. 13). Courtenay, BC: Connections Publishing.

[344] Schein, E.H. (1999) *The Corporate Culture Survival Guide: Sense and Nonsense About Culture Change* (p. xvi). San Francisco, CA: John Wiley & Sons, Inc.

The empirical goal of my research study was to elicit and depict the shared mental model from which MLTI participants and the education community at large develop their use of technology and how the mental model fosters a resistance to other conceptions of technology use in education.

I chose to focus my attention on the teachers in the MLTI because I agree with Cuban's assertion that teachers are the gateway to change.[345] I also chose to gather data on the teachers' perceptions because "perceptions count" – that is, "if men perceive a situation as real, that situation is real in all of its consequences."[346] Eliciting participant interpretations in the form of "teachers' own descriptions of their classroom practices"[347] has precedence in other studies of one-to-one laptop computing, the most prominent examples being Rockman's studies of the Microsoft's Anytime Anywhere Learning program.[348]

The perceptions and interpretations of technology are both individually held and shared among the teacher participants. These shared interpretations and individual perceptions mutually and simultaneously shape one another in the social dynamic of the MLTI effort in particular and the education community in general. These perceptions and interpretations are not directly knowable.

345 Cuban, L. (1986) *Teachers and Machines: The Classroom Use of Technology Since 1920*. New York: Teachers College Press.

346 Rogers, E.M. (1994) *A History of Communication Study: A Biographical Approach*. New York: The Free Press. As cited in Rogers, E.M. (1995) *Diffusion of Innovations, Fourth Edition* (p. 111). New York: The Free Press.

347 Rockman, S. (1997) *Report of a Laptop Program Pilot, A Project for Anytime Anywhere Learning* (p. 35). San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/resrch_1.rtf>

348 Rockman, S. (1997) *Report of a Laptop Program Pilot, A Project for Anytime Anywhere Learning*. San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/resrch_1.rtf>;
Rockman, S. (1998) *Powerful Tools for Schooling: Second Year Study of the Laptop Program*. San Francisco, CA: Rockman ET AL. <http://www.microsoft.com/education/download/aal/research2.rtf>

However, they can be revealed and understood through inference "from inquiry of participant activity and an analysis of socially constructed artifacts."[349]

Clues to the mental model underlying current technology practices and the extent of its pervasiveness within the MLTI were found through content analysis of MLTI documentation. I made extensive use of documentation and printed text as data sources to inform the study. These texts came in the forms of first-person written accounts of technology practices, descriptions of technology-rich classroom projects, success stories written by teachers for the benefit of the MLTI community, vision statements as to how technology is to be used, manuals and other handouts from technology training sessions, notes from teachers' meetings, official memos, and distributed guidelines and recommendations for technology use in the MLTI. Data sources like these, according to a growing community of researchers and in my own experience, are better articulated and more reflective than verbal statements.

Written texts are important for qualitative research "because the information provided may differ from and may not be available in spoken form."[350] While interviews and observations can serve as valuable sources for research, "the interpretation of mute evidence – written texts and artifacts" that served a practical purpose within a community – offers a lifetime that "can be

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349 Tillquist, J. (1996) *High Concepts and Low Hanging Fruit: Using Information Technologies to Mobilize Organizational Change* (p. 29). Unpublished Ph.D. dissertation, University of California, Irvine.

350 Hodder, I. (2000) "The Interpretation of Documents and Material Culture" (p. 704), in Denzin, N.K. and Lincoln, Y.S., eds., *Handbook of Qualitative Research, Second Edition* (pp. 703-715). Thousand Oaks, CA: Sage Publications, Inc.

separated across space and time from its author, producer, or user."[351] Such artifacts have a permanence that allows them to be analyzed by anyone with access to the artifacts, while events and interviews have a transience that provides the primary observer a position of authority with regard to the presentation and interpretation of the data.

The sources of textual data found within the MLTI provided concrete forms of data that significantly differ from spoken words gathered in an interview in the sense that these texts were written to do something[352] – to be used by the MLTI community for particular purposes. Indeed, it could be argued that these texts are uniquely valuable sources of data precisely because they are not overt, self-conscious speech[353] solicited as responses to potentially leading questions from the interviewer that could influence the findings.[354] In short, written texts offer the advantages of being widely available and accessible to the reader for his or her own comparative assessment and being uncompromised by the intrusion of the researcher.

Data collection extended from the beginning of the 2002-2003 school year (Year 1) through six months into the 2003-2004 school year (Year 2). In addition to content analysis of documents, direct observation was another means for uncovering taken-for-granted assumptions and the mental model underlying technology use. At the beginning of the MLTI, I established social

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351 Hodder, I. (2000) "The Interpretation of Documents and Material Culture" (p. 703), in Denzin, N.K. and Lincoln, Y.S., eds., *Handbook of Qualitative Research, Second Edition* (pp. 703-715). Thousand Oaks, CA: Sage Publications, Inc.

352 Ricoeur, P. (1971) "The Model of the Text: Meaningful Action Considered as Text," *Social Research*, 38, pp. 529-562.

353 Hodder, I. (2000) "The Interpretation of Documents and Material Culture," in Denzin, N.K. and Lincoln, Y.S., eds., *Handbook of Qualitative Research, Second Edition* (pp. 703-715). Thousand Oaks, CA: Sage Publications, Inc.

354 Mishler, E. (1986) *Research Interviewing: Context and Narrative*. Cambridge, MA: Harvard University Press.

contacts with MLTI participants, focusing on teachers in particular. My interactions with MLTI participants began in the summer of 2002, the summer when laptop computers were distributed to seventh-grade teachers. I attended the MLTI summer training workshops for seventh-grade teachers, teachers' meetings at local schools, and a technology conference for MLTI teachers held at the University of Maine at Orono. In the fall of 2002, I visited classrooms, had coffee break in the teachers' lounge, ate lunch with teachers and students, participated in hallway conversations, met with principals, and even had an opportunity to help a teacher hand out laptop computers to the seventh-grade class. In total, I visited nine MLTI schools, including two demonstration schools. I conducted limited classroom observations and observations of teacher meetings in two schools, with one day spent at each school.

I maintained contact with 39 seventh-grade teachers from 26 schools for a period of eighteen months (September 2002 to February 2004) and 33 eighth-grade teachers from 13 schools for a period of six months (September 2003 to February 2004). I became acquainted with the majority of these teachers at the MLTI training sessions that I attended: two MLTI training sessions for seventh-grade teachers during the summer of 2002 and three MLTI training sessions for eighth-grade teachers during the summer of 2003. The remainder of the teachers was referred to me by the teachers I already had contact with. The teachers taught in middle schools of different sizes and geographical locations and covered a range of subject areas including science, math, social studies, history, English/language arts, reading/writing/literacy, physical education, and special education. The number of years spent working as a teacher ranged from 1 to 38 years, with the average tenure being 18 years (in 2003). Each teacher was contacted by telephone several times over the data collection period. Informal phone conversations, lasting from 20 minutes to one hour, with this group of teachers served to corroborate my findings and helped to refine and augment my emerging analyses of how technology use is shaped by the expectations and taken-for-granted assumptions of individuals and their community.

A case study is an in-depth investigation of an individual, especially as an exemplary model of a particular phenomenon.[355] A case study is viewed as being valued in its own right, and while findings can raise awareness of general issues, the aim is not to generalize the findings to other cases.[356] Case studies of key individuals proved to be especially valuable in learning about how an entrenched mental model fosters a resistance in the community to other conceptions of technology use in education. For this thesis research, case studies were conducted on two individuals whose experiences with technology use departed from the widely-adopted pattern within the MLTI.

For a qualitative study, "the goal in insuring study validity is not to achieve replicability and predictability over a statistical population but to demonstrate conceptual robustness,"[357] in the case of this particular study, of mental models as a useful theoretical construct for examining the current approach to technology use in education. Documentary analysis, direct observation, and case studies, taken together, insure the representativeness and validity of the data and the findings of this study.

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355 Bogdan, R. and Biklen, S. (1982) *Qualitative Research for Education: An Introduction to Theory and Methods*. Boston, MA: Allyn and Bacon, Inc.

356 Ibid.

357 Tillquist, J. (1996) *High Concepts and Low Hanging Fruit: Using Information Technologies to Mobilize Organizational Change* (p. 33). Unpublished Ph.D. dissertation, University of California, Irvine.

"The task of converting field notes and observations about issues and concerns into systematic categories is a difficult one. No infallible procedure exists for performing it."[358]

> The qualitative analyst's effort at uncovering patterns, themes, and categories is a creative process that requires making carefully considered judgments about what is really significant and meaningful in the data. Because qualitative analysts do not have statistical tests to tell them when an observation or pattern is significant, they must rely on their own intelligence, experience, and judgment.[359]

In my study of technology use patterns within the MLTI, data analysis began with the process of compiling and sorting through the data looking for "recurring regularities" that represent emergent patterns to be analyzed and interpreted.[360] I used an "inductive analysis" approach to interpret the data. "Inductive analysis means that the patterns, themes, and categories of analysis come from the data; they emerge out of the data rather than being imposed on them prior to data collection and analysis."[361]

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358 Guba, E.G. (1978) *Toward a Methodology of Naturalistic Inquiry in Educational Evaluation*. Los Angeles: UCLA Center for the Study of Evaluation. As cited in Patton, M.Q. (1990) *Qualitative Evaluation and Research Methods, Second Edition* (p. 405). Newbury Park: Sage Publications.
359 Patton, M.Q. (1990) *Qualitative Evaluation and Research Methods, Second Edition* (p. 406). Newbury Park: Sage Publications.
360 Ibid., p. 403.
361 Ibid., p. 390.

I employed both “indigenous concepts” and “sensitizing concepts” in my interpretation and analysis of the collected data.[362] Indigenous concepts are the meanings “developed and articulated by the people studied.”[363] They reveal “how people construe their world of experience.”[364] “In contrast to indigenous concepts, sensitizing concepts are concepts that the analyst brings to the data” from existing theoretical frameworks and research literature in the relevant fields.[365] “The inductive application of sensitizing concepts is to examine how the concept is manifest in a particular setting or among a particular group of people.”[366] To bring focus to the process of data analysis, I used concepts from cognitive science, organizational learning theory, management research, and technological change research – the mental models concept being the most centrally used lens in structuring data interpretation.

I attempted to present “the actual data on which the analysis is based” as much as possible throughout my presentation of the research findings.[367] “By presenting respondents in their own words and reporting the actual data that were the basis of ... interpretation, [the researcher] permits readers to make their own analysis and interpretation.”[368]

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362 Patton, M.Q. (1990) *Qualitative Evaluation and Research Methods, Second Edition* (pp. 390-391). Newbury Park: Sage Publications.
363 Ibid., p. 390.
364 Frake, C.O. (1962) “The Ethnographic Study of Cognitive Systems” in Gladwin, T. and Sturtevant, W.C., eds. *Anthropology and Human Behavior* (pp. 72-85). Washington: Anthropological Society of Washington. As cited in Patton, M.Q. (1990) *Qualitative Evaluation and Research Methods, Second Edition* (p. 405). Newbury Park: Sage Publications.
365 Patton, M.Q. (1990) *Qualitative Evaluation and Research Methods, Second Edition* (p. 391). Newbury Park: Sage Publications.
366 Ibid., p. 391.
367 Ibid., p. 392.
368 Ibid.

APPENDIX B: CHRONOLOGY OF THE MLTI

2000

2 March Governor Angus King announced his proposal to give laptop computers to all 7th-grade students in Maine. He also announced his intention to provide laptop computers for public middle school teachers. The laptop initiative would start in 2002, giving schools time to prepare for the new technology. The initial proposal was to create a $50 million endowment for the laptop program, the interest of which would eventually pay for the cost of laptops for all of Maine's students.

20 March Governor King clarified his proposal to the public, stating that the laptop computers would be school-owned and not given directly to students.

22 March The Legislature's Education Committee voted 11-1 against Governor King's laptop proposal.

April The Legislature approved a supplemental state budget that included a $30 million budget for unspecified school technology needs. A Maine Learning Technology Endowment was created, financed with this $30 million.

July The Legislature and Governor King agreed to allocate $20 million from the state surplus to the budget for unspecified school technology needs.

August A small rural school district in Guilford decided to buy its own laptops with a $100,000 grant from a local textile company, Guilford of Maine. The laptops were distributed among the district's 5^{th}-8^{th} grade students.

7 September The Task Force on the Maine Learning Technology Endowment first convened. The 17-member Task Force consisted of 6 Legislators, 3 state agency officials (representing the Department of Administrative and Financial Services, the Department of Education, and the Public Utilities Commission), and 8 public members from education, business, finance, and technology sectors. Their task was to make recommendations to the Legislature on how to best use $50 million to address school technology needs.

2001 **January** After 9 meetings, the Task Force issued a final report of findings and recommendations, titled *Teaching and Learning for Tomorrow: A Learning Technology Plan for Maine's Future*.

An estimated state revenue shortfall of $200 million put Governor King's laptop proposal in jeopardy. Supporters of the laptop proposal worried that the Maine Learning Technology Endowment would be used to cover the shortfall.

May The Legislature agreed on a budget that diverted $20 million from the technology endowment, leaving $30 million for the purchase of laptop computers for 7^{th}-grade students.

December Apple Computers, Inc. was chosen by the State to be the supplier of laptop computers, software, teacher training, and technical support.

2002 **January** A 4-year, $37 million contract was signed. Apple agreed to provide iBooks for a cost of $300 per user. One middle school from each of the nine superintendent regions in Maine were selected by the Department of Education to be demonstration schools.

March The first shipments of iBooks arrived at the nine demonstration schools. A total of 675 iBooks were delivered, enough to equip several classrooms of 7th-grade students at each school.

June Apple CEO Steve Jobs visited Maine to promote the laptop program.

July Two legislators asked Attorney General Steven Rowe if Maine could break its contract with Apple Computer. Rowe replied that to do so would cost the state at least $100,000 and would have impact on Maine's creditworthiness.

July – August MLTI teacher training by Apple and SEED provided to 7th-grade teachers.

14 – 16 August The Learners, Laptops, and Powerful Ideas Conference held at the University of Maine at Orono.

September About 17,000 laptops were distributed to 7th-grade students and about 3,000 laptops were distributed to 7th-grade teachers in 241 public middle schools in Maine.

2003 **January** Governor King left office after serving the maximum two terms. Current Governor John Baldacci said he is determined to see through the project that was the brainchild of his predecessor.

March Mid-Year Evaluation Report issued by the Maine Education Policy Research Institute. The report was presented to the Legislature's Education Committee, which was considering taking money away from the laptop program in order to increase general purpose aid to local schools. The committee recommended using other funds instead.

April – May Department of Education personnel held the first round of MLTI Content Area meetings.

June End of the first full year of the laptop program.

July – August MLTI teacher training by Apple and SEED provided to 8th-grade teachers.

September More than 16,000 laptops were distributed to 8th-grade students and their teachers.

15 September – 30 October Department of Education personnel held the second round of MLTI Content Area meetings.

2004 **June** End of the second full year of the laptop program. Providing laptop computers to high school students continue to be discussed.