THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGY IN MATHEMATICS - A DOUBLE IRONY?

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ABSTRACT
When the microcomputer was introduced to schools in the late 1970's the connection between it and mathematics seemed more than obvious. Educators would have been excused if they thought that technology (and the computer in particular) was destined to be the exclusive preserve of the mathematics classroom. How wrong could they have been! In the 1990's, the Internet exploded onto the scene adding enormous value to almost all disciplines except, it may have seemed, mathematics. An irony perhaps. The double irony, however, is that with a current emphasis on real-world problem solving and the goal of integrating mathematics into other disciplines, (particularly science) mathematics will also benefit greatly from the Internet. Based on article by Wright (2002), this paper provides a perspective on the use of information and communication technology (ICT) in mathematics including how it evolved and examples of its contemporary use. While it is clear that ICT has already had a significant and positive influence on mathematics it is also clear that there will be more to the story. The explosion of activity surrounding the Internet alone ensures that this will be the case.

KEYWORDS
Mathematics, information and communication technology, computers

INTRODUCTION

With the introduction of the slide rule and, subsequently, the electronic calculator, few would argue that mathematics classrooms were among the first and most significant beneficiaries of the use of technology. The future looked good. At that time, most educators would have been excused if they thought that the computer was destined to be the exclusive preserve of the mathematics classroom. How wrong could they have been! In the 1990's, the Internet exploded onto the scene adding enormous value to almost all disciplines except, it may have seemed, mathematics. Social studies, where one once might have been excused for asking "how can you use a computer in the history classroom" suddenly lives through the Internet. An irony it seems. Mathematics was left with its rules, its logic, its algorithms, its twenty-five-year-evolved calculator, and, of course, the spreadsheet. The double irony is that, with its current emphasis on real-world problem solving and the goal of integrating mathematics into other disciplines (particularly science) mathematics will also benefit greatly from the Internet.

Until recently at least, there existed a spectrum of opinion on the benefit of using Information and Communication Technology (ICT) in mathematics and science. Some, such as Fisher (1999) readily acknowledge the potential benefit but still raise questions through remarks such as "There is little doubt the technology can make a difference, but the core question remains: Does Internet access and the use of computers actually raise students' achievement in science and math? Does it justify the roughly $6 billion to be spent this year on technology for K-12 schools?" Others, such as Skinner (1997) openly challenged the value of using ICT (and the Internet in particular) by expressing the view that "there is little that a science student and even less that a math student can learn from the Internet".

Writing about the use of information and communication technology (ICT) in any discipline is challenging. Rapidly evolving technology combined with the diversity of use of ICT, even within a single discipline, virtually ensures that this will be the case. With this in mind, this article lays no claim to comprehensiveness but instead uses selected examples to provide a perspective on the use of ICT in the schools. It is fully recognized that readers may be aware of significant developments or topics that are not explicitly referenced.

THE EARLY YEARS

The Slide Rule

For all practical purposes the slide rule represented the introduction of technology into the mathematics classroom in the modern era. Until the mid nineteen seventies, it was not uncommon for teachers to hang eight foot slide rules on the blackboard to acquaint high school mathematics students with a technological manifestation of logarithms and trigonometric functions. In the quest for greater precision, different slide rule configurations emerged. Circular slide rules, though unwieldy, benefited from the large circumferences that circle geometry allowed. The ultimate in both precision and portability in a slide rule was apparent in a device called the *Otis King*. Approximately six inches in length, the *Otis King* featured a telescoping design with a sliding cylindrical cursor. The scales spiraled around the telescoping cylinders and, if unwrapped, would have been sixty-six inches long.

The Calculator

In the mid-to-late 1970’s, the electronic hand-held calculator became prominent, quickly and mercifully replacing the slide rule. Light emitting diodes gave way to liquid crystal displays and programmable calculators became commonplace. The introduction of the electronic calculator (programmable ones in particular) witnessed the beginning of significant controversy in the use of technology in the mathematics classroom. The primary concern was that if students used calculators, they would no longer master the basics. Equity of access and the use of calculators on exams were other issues.

The debate as to whether students should be allowed to use calculators had almost subsided only to be rekindled with the introduction of sophisticated graphing calculators. A key issue here is that many mathematics courses now *require* the use of such a calculator. As a consequence of this, the cost issue reemerged even though good graphing calculators today are cheaper than their less capable predecessors.

Unlike its predecessor (the slide rule) the potential of the electronic calculator was probably never fully exploited in the mathematics classroom. No sooner was one type of calculator introduced than a more powerful, multifunctional version became available. How many students developed a working familiarity with the (approximately) forty functions available on even the earliest calculators let alone with the programmability that became available on subsequent generations?

While calculators continue to have a firm presence in the mathematics classroom, many of their more profound functions have been assumed by the personal computer. In many ways, as computer technology becomes more miniaturized, the distinction between the computer and the calculator will continue to blur or even disappear - the term hand-held computer is a testament to this.

The Microcomputer

The microcomputer burst on the scene in the late 1970’s carrying with it the promise of revolutionizing teaching and learning. The introduction of this innovation and its perceived potential has been described by many authors (e.g., Wright, 1993). The potential of the microcomputer was slower to be realized than many had anticipated. It is certainly true that an era of software development and experimentation needed to take place. Despite this, the connection between mathematics and the computer was apparent from the start and was manifested in many ways. In the absence of appropriate applications software a great deal of attention was focussed on programming. Students of all ages were taught to program the first microcomputers as were teachers. Early applications featured the development of drill-and-practice programs. Typically, these programs were used to promote the development of basic computational skills - they are still around today. Between drill programs and the focus on computer programming it is not surprising that a strong connection was made between the computer and mathematics. Early uses of the microcomputer thus frequently fell to mathematics teachers (and business education teachers, who traditionally taught programming).

The appropriateness of integrating the computer into *all* subject areas *was* acknowledged from the beginning and thus, in addition to programming, early initiatives focussed on the search for applications software. This proved to be a very fruitless task. Educational software was either unavailable or of questionable quality and value. Among the "better" educational applications were the mathematics drill-and-practice packages. The scarcity of quality courseware led to a natural relapse into the teaching of programming while the world waited for the situation to improve. Who better to understand and teach programming than mathematics teachers? Programming was defended from a number of perspectives including its perceived value in fostering the development of problem solving skills. Passionate debates raged about which language was the best and programming subcultures emerged (e.g., Bork, 1987; Maddux, 1989). By the late 1970's, general-purpose productivity and utility software were available. Significant among these for mathematics was the spreadsheet and the plotting utility. The plotting utility has survived to this day. It has evolved greatly in sophistication and user friendliness and is as likely to be found in a graphing calculator as it is on a computer.

The microcomputer was clearly the leading edge of the ICT revolution and its introduction was attended by a great deal of euphoria (evangelism even). As visions for the impact of the microcomputer in education failed to materialize, however, this euphoria abated, only to re-emerge with a vengeance as a result of the Internet. Technology has come a long way in a relatively short time. Using examples from the literature, the remainder of this article will provide a perspective on how ICT is being used in mathematics classrooms.

CLIMATE FOR THE USE OF ICT IN THE SCHOOLS

The context for the use of ICT in education is changing dramatically and initiatives are under way to ensure that the technological literacy of students will not be left to chance. In an article that polled several experts and stakeholders on their vision of the future of technology education, Ritz (2000) stated that "by 2010, technology education will be the new basic. It will become the fifth core of the school curriculum". In the Province of Alberta, Canada, 2010 has arrived. Beginning in September 2000 a new program of Studies called Information and Communication Technology became mandatory for all students in Kindergarten to Grade 12 – the fifth core subject (Alberta Learning, 2000). Defining characteristics of the program are that it is mandatory, its goals and objectives are distributed across all grades and subjects, and integration is paramount. The intent of the program is to emphasize technology as an approach to problem solving, a way of thinking, a process as opposed to merely a tool. Similar initiatives are evident in the US where ICT standards have been defined for both students and teachers through the I International Society for Technology in Education (ISTE), National Educational Technology Standards for Students and the ISTE, National Educational Technology Standards for Teachers (ISTE, 1998; ISTE, 2000). As well, the National Council of Teachers of Mathematics (NCTM) curriculum standards clearly embraces the use of ICT (NCTM, 1989).

USE OF ICT IN MATHEMATICS

This article attempts to capture the essence of how ICT is being employed in mathematics by touching upon selected topics and examples. In order to accomplish this, a classification scheme has been chosen. There is nothing absolute about the scheme, it is merely a convenient and sensible structure under which to organize the examples presented. There are bound to be innovative and effective applications that are not mentioned here, either because they were not unearthed or because of the space limitations of this article.

The Calculator (again)

The calculator, in popular use since at least the mid 1970's is still very much in evidence today though in a highly evolved form. In an article that describes technologies that can be used to achieve the NCTM standards as they apply to the high school algebra curriculum, Harvey, Waits, and Demana (1995) emphasize the value of the graphing calculator. They acknowledge that other general purpose computing systems such as the IBM Math Exploration Toolkit, Derive, Mathematica, and Maple as well as others can also contribute significantly to meeting the NCTM standards and likely in a broader way. They conclude, however, that such tools should not be chosen for regular use by students due to their high cost and lack of user friendliness. It is tempting to think that the observations of Harvey, Waits, and Demana (1995) might be dated by the rapidly evolving nature of technology but such is not the case. Maurer (2000), for example cites Hawkins, Stancavage, and Dossey (1998) who state that in 1996, ninety five percent of twelfth graders used calculators in class and sixty two percent used graphing calculators. The virtues of using graphing calculators have been widely extolled though not entirely without concerns (e.g., Harvey, Waits, and Demana, 1995; Drier, Dawson, and Garofalo, 1999; Barbour et al, 1999; Cuoco and Goldenberg, 1996; Sellinger and Pratt, 1997). On the particular issue of using calculators in exams, Sellinger and Pratt state that "We would advocate that the examination should be instead reconceptualised in terms of what can now be explored that could not be so readily or easily have been explored before …"

Tools and Techniques

First of all, what is implied by this section? It is perhaps easier to say what is not implied. Excluded from this category is any use of ICT which is either global or which substantially represents the way of doing things. For example, excluded from the category would be online learning since this would be a defining characteristic of the mathematics class. The tools and techniques category reflects the most diversity in the use of ICT.

Utility Software

Utility software can be thought of as software that has a high degree of universality and/or does not have subject specificity. Classic examples of this tool are the plotting utility and the spreadsheet. The spreadsheet is a particularly powerful and generic utility, which, though mathematical by nature, finds applications in almost every subject. So pervasive and significant is the spreadsheet that it merits separate consideration. A myriad of other utilities exists many of which are either subject specific or targeted to some degree. A targeted utility may have simulation capabilities and can be used to address a single objective, topic, or even several modules of a curriculum. An examples of this is described by Furner and Ramirez (1999) who use a tool called *ArcView* can be used to teach the concept of map projections by integrating mathematics, science, and geography.

Programming Languages

Though still recognized for their usefulness in developing problem solving skills conventional programming languages, such as BASIC and Pascal, have all but disappeared from the mathematics classroom (e.g., Casey, 1997). Logo, which for a time enjoyed almost cult like status, has survived though mostly at the lower grade levels (see Kajander, 1999 for example) and with significantly reduced popularity. The evolution of programming languages has led to a diverse array of tools such as ISETL, Mathematica, and Maple. These systems differ appreciably both in their character and their interface but they retain many of the characteristics of programming languages (Cuoco and Goldenberg, 1996). A small step further down the evolutionary road of programming has led to tools such as *Geometers Sketchpad*, which also incorporates significant simulation capabilities. Developments in this area suggest that the term "programming language" is perhaps too narrow. Terms which are gaining in popularity include computing system, computing environment, and (where simulation capability is very evident) microworld.

The Spreadsheet
One might ask why the spreadsheet is singled out. Surely it is a utility. But then again, with its penchant for formulas and even macros isn't it a programming tool? The answer to both of these is "yes" but the spreadsheet is so versatile it has become ubiquitous. Its significance can hardly be overstated and thus, it simply warrants separate consideration. In mathematics the spreadsheet has become such a powerful and pervasive tool that some observers have suggested that math courses, almost in their entirety, can be based on its use (e.g., Bretl, 1994). In addition to its powerful computational capability, the spreadsheet provides for the graphical representation of data. Wright (1997) describes a variety of ways in which the spreadsheet can be used for problem solving in the mathematics classroom and presents a number of illustrative examples. Use of the spreadsheet in mathematics allows students to solve problems that might otherwise have had to wait until more advanced intellectual development had taken place (the ability to solve calculus problems for example). They also allow connections to be made that might otherwise not have been apparent. At least, concludes Wright:

> *In offering a viable complement or alternative to existing problem-solving strategies, the use of the spreadsheet certainly affords the opportunity to accommodate a wider spectrum of learning styles. In many ways, technology-based tools such as the spreadsheet can facilitate the restructuring and redefinition of mathematics curricula.*

Abramovich and Nabors are among many observers who have noted that spreadsheet use is consistent with the NCTM goal of encouraging students to explore mathematical ideas (Abramovich and Nabors, 1997).

Drill and Practice
One of the earliest mathematics applications, drill and practice, is still alive and well. Typically, drill-and-practice applications provide customized practice on a skill that has already been taught. Invariably, the application incorporates a records management system that monitors and reports on student achievement. In a study conducted by Manoucherhri (1999), one hundred and forty school districts in the state of Missouri were surveyed regarding their use of ICT in mathematics. Almost half of the combined one hundred and eighty one middle and high school teachers who responded indicated that they used computers for individualizing instruction and primarily for drill-and-practice activities. Although still in use in middle and high schools, drill and practice is more prevalent in the lower grades and typically reflects motivational inducements such as multimedia and gaming. As Fisher (1999) summarizes it "the consensus is that software for the classroom has greatly improved in recent years as well – a long jump from older math software that was merely a computerized version of boring and repetitive in-class drills".

Simulations
Ever present in the mathematics classroom, computer simulations imply that problems or explorations can be conducted by allowing the learner to manipulate variables. Simulations typically permit a number of possibilities to be explored without having to perform complex or laborious calculations. Lederman and Niess (1999) note that some would argue against the use of simulations on the grounds that it is not doing real mathematics. They strongly counter this argument by stating that even when they are not using simulation tools, students are not doing authentic math the way that mathematicians do. Many of the tools referred to above, such as *Geometers Sketchpad* and the spreadsheet, permit simulations to be carried out.

Collaborative Initiatives
There is increased evidence of collaborative activities in the mathematics classroom (e.g., Miller and Castellanos, 1996; Wilson, 1999). Miller and Castellanos describe a collaborative project (designed to integrate mathematics and science) that employs a constructivist approach to learning. Using common

data, a groupware application (*The Virtual notebook System*) and a scientific programming application (*MATLAB*), a group of thirty high school juniors were asked to address an open-ended assignment which focussed on using climatological data and facts about the growth of corn to determine the optimal planting time by region of the state. Working in a networked lab, the students were asked to produce two types of page, one which was available to the group (and to which the group could add) and another which was private (the individual student's constructed knowledge). Within a collaborative environment "the intent was, to construct their own core of knowledge on which other students could build – NOT to produce an ideal that other students should strive to produce".

Other Tools and Techniques
There are numerous narrowly targeted software applications and utilities available to support mathematics as well as hardware innovations such as electronic whiteboards, smart boards etc. (e.g., Knowles, 1999; Niess, 1999).

Alternative Delivery
In its broadest sense, alternative delivery implies a non-traditional approach to instruction (Wright, 1999). Beyond that, it is interpreted here to imply that the use of ICT is a defining characteristic of the modus operandi. This could mean that ICT is either at the heart of the delivery system or is the means by which most of the course objectives can be achieved. According to this perspective, the collaborative, initiatives referred to previously as well as the math course described by Bretl could be considered to be alternative delivery. Heid and Zbiek (1995) describe a course, which is based on a curriculum called Computer Intensive Algebra (CIA). This course focuses strongly on the use of ICT to develop a rich understanding of the fundamental concept of algebra.

More readily identifiable as alternative delivery, however, are things like Computer Assisted Instruction (CAI) and online learning. CAI in mathematics pre-dates the microcomputer (e.g., see Macken and Suppes, 1976; Poulsen and Macken, 1976). In its early forms CAI had a decidedly question-and-answer flavour, a limitation that did not endear it to educators in general. With the emergence of more versatile and powerful authoring systems CAI has improved significantly and regained some of its appeal. It is now more likely to be found under its new and more palatable identity, Computer Based Learning (CBL). Research on the effectiveness of CBL in mathematics has often shown the approach to be beneficial to learners, particularly those who were performing below grade level. Recently, Macnab and Fitzsimmons (1999) reported on the evaluation of a CBL system called *The Learning Equation* (TLE) that was produced by Nelson Canada in partnership with the Canadian western provinces. While acknowledging some limitations in the commissioned study, these researchers still concluded that: "... given the weaknesses and limitations, the trends are strongly indicative of the efficacy of implementing TLE in the mathematics education of grade 9 students. TLE appears to provide efficient methods of instruction that have led to enhanced performance."

Opinion on the value of CAI is divided. Maurer (2000) contends that the use of computers as tutors has not grown because their ability to tutor has not has not improved enough and schools have not turned heavily to such software. These sentiments are supported by Christmann, Badgett, and Lucking (1997).

Online learning, or virtual schooling as it is often referred to, represents a major forefront in alternative delivery. It can be found in many forms including computer-assisted video conferencing and web-based learning. With the former, the potential exists, for example, for an exemplary mathematics teacher to simultaneously deliver instruction in real time to math classes in a number of schools who have scheduled the same course at the same time. With the latter, students may learn primarily from a web-based course (either remotely or onsite) while the teacher acts as a facilitator/mentor/coach. Regardless of its form, it is unlikely that alternative delivery will have as much impact on K-12 schooling as it will in the post-secondary environment.

The Internet

As educators worked to explore the potential of the microcomputer a quiet revolution was underway in the world of telecommunications and then suddenly, (seemingly) there was the Internet. To describe the Internet as being a phenomenon is an understatement, it may well prove to be the missing piece of the puzzle. The very powerful combination of computers and communications technologies has led to a renewed understanding of the potential of ICT in education. The promise is still alive! That many either did not see it coming or at least, completely underestimated its significance, is evidenced by Maurer (2000) who was assessing the outcome of his 1984 predictions regarding the changing face of mathematics. While acknowledging that he was aware of the prospect of a WWW-like communications infrastructure he said that:

> *I guess that I just did not think that people would bother to use it or that it would make much difference, because of my narrow focus on curriculum and lack of attention to the method of delivery. All right, the Web is all the rage, but how much difference does it make to mathematics education? So far, not too much.*

Perhaps the most obvious way that the Internet can support the achievement of mathematics goals is through its ability to support the integration of disciplines (mathematics and science in particular). Integration is a recurring and pervasive theme in the research literature (e.g., Clark et al, 1998; Drier, Dawson, and Garofalo, 1999; Gerber and Shuell, 1998). The immediacy of the Internet provides teachers and students with the opportunity to access real-world data on which to apply their mathematical skills and models. Such data can be used for "conventional math", or as input for graphical calculators and computing systems. In so doing, students are able to substantially achieve the major NCTM standard of applying mathematics to the world beyond the classroom. Schotsberger (1999)describes a pilot project on the use of a web site called *INSTRUCT* (**I**mplementing the **N**CTM **S**chool **T**eaching **R**ecommendations **U**sing **C**ollaborative **T**elecommunications) which supports just-in-time professional development for mathematics teachers.

Not everyone is equally enthusiastic about the use of the Internet, even for finding information. Robertson (1999), for example, questions its value for finding mathematical information. He cites three areas of concern, notably, the difficulty of zeroing in on an answer, the credibility of that answer, and the ease with which academic integrity can be compromised. To reinforce the first point, Robertson suggests using the term “airy” to search for information on Airy functions. He indicates that you would be more likely to come up with hits on towns in several states, the Ponoco Mountains in Pennsylvania, and a host of products and services before finding the first reference to Airy Functions. He asserts that you would have been better off to go to the library. Robertson’s experiences with finding things via the Internet adds credence to the notion of it being the world’s largest library with all of the books thrown on the floor.

DISCUSSION – WHERE ARE WE HEADED

While it is clear that ICT has already had a significant and positive presence in mathematics it is also clear that there will be more to the story. The explosion of activity surrounding the Internet alone ensures that this will be the case. The use of ICT in support of teaching and learning, however, will continue to raise many issues and challenges.

Shaffer and Kaput (1999) discuss the introduction of computational media from a cognitive evolutionary perspective and argue that it is leading us into a virtual culture dependent on the externalization of symbolic processing. They contend that “in a virtual culture students will have new ways of sharing new forms of mathematical experiences, mathematical representations, and ultimately, mathematical understanding”.

While no one will doubt the need to produce technologically literate students, questions will continue to arise as to the effectiveness of using ICT to achieve the other goals of teaching and learning. Does the use of ICT support the learning of English, Social Studies and Mathematics for example and at what cost. This article has provided many positive examples of the use of ICT in mathematics and parallels undoubtedly exist in other subject areas. Since the introduction of the microcomputer, however, there has been a prevailing tendency to presume that most applications of ICT are inherently good, often to the degree that those closest to the action saw little need to conduct thorough evaluations. Early implementations of Logo and its subsequent decrease in popularity are a classic testimonial to this as well as to the fashionable nature of some ICT applications. Recently, Middleton and Murray (1999) conducted a general study to determine the impact of a technology rich environment on achievement in reading and mathematics at the grade four and grade five levels. In this study, teachers were asked to assess their own level of technology implementation. This information was used as an indicator of the degree to which technology was being implemented in a particular classroom environment (technology richness). Student achievement on standardized tests was then compared as a function of which environment they were in. In regard to mathematics, this study found that "the level of technology used by the teacher did have a significant effect on the mathematics academic achievement of fifth grade students, but not on fourth grade mathematics students".

And what about the cost of technology? Fisher (1999) notes that "There is little doubt the technology can make a difference, but the core question remains: Does Internet access and the use of computers actually raise students' achievement in science and math? Does it justify the roughly $6 billion to be spent this year on technology for K-12 schools?" There is no shortage of detractors who argue strongly (and sometimes effectively) against the use of technology in the schools based on its cost.

According to Jonassen (1996), many of the tools described in this article can be classified as "Mindtools". Jonassen defines Mindtools as being "computer applications that require students to think in meaningful ways in order to use the application to represent what they know." He goes on to say that in his opinion "the most appropriate use of the computer is as a cognitive tool for accessing information and interpreting and organizing personal knowledge". The use of Mindtools is clearly consistent with what Jonassen sees as the new theory of learning, constructivism, which he describes as follows:

> *Constuctivism is concerned with the process of how learners construct knowledge. How learners construct knowledge depends on what they already know, which depends on the kinds of experiences that they have had, how they have organized those experiences into knowledge structures, and the beliefs they use to interpret objects and events that they encounter in the world.*

In bringing reality to the notion of time and place independent learning, the Internet has broken down the barriers to who can develop curriculum. Those who see prospect in the development and delivery of curriculum are no longer constrained by the need for a teacher and/or a classroom. Noam (1995), for example, sees ICT opening the doors wide to the privatization of education. The convergence of television and Internet technologies enhances the prospect of third-party development of curriculum as evidenced by Jones (2000) – an ex mathematics teacher and current head of programs for the British Broadcasting Corporation (BBC) Wales. In his article, Jones says asks:

> *Is this a role for the BBC? I would say yes, for two reasons – because it should and because it can. The opportunity is there for us to use our depth of production experience to contribute to a new and lively age of learning.*

And the Internet? An amazing communications infrastructure which supports everything from access to information to alternative delivery. If ICT is to ever fulfill the perennial promise of revolutionizing education, time will undoubtedly show that the Internet (or a highly evolved derivative) was a critical piece of the puzzle. Already in the US, ninety 95% of schools and 72% classrooms are connected to the Internet (CEO Forum on Education and Technology, 2000).

While for the most part the literature extols the virtues of the Internet some observers, such as Robertson (1999), add a note of caution.

> *Let me state quite clearly my enthusiasm for the power brought to mathematics and teaching by this technology (the Internet). But there is a giddiness about in the land, and one that masks the pitfalls, frustrations, and dangers of this technology for us and our students. There is a great responsibility for all of us to help each other and our pupils to tame this beast, and to ensure, as best we can, that it remains our servant and not our master.*

In a less than positive article on the use and relevance of ICT in schools, Skinner (19970 states that "There is little that a science student and even less that a math student can learn from the Internet". He closes his article by responding to a 1996 comment, which he says, was made to Education Week by the executive of a large computer company. The executive's comment apparently was "education is the only industry still debating whether technology is a good idea". Skinner's response was:

> *In the case of computers, too many educators and political leaders are falling for this line. The burden should not be on American education to prove that it is up-to-date. Rather the burden should be on the computer industry to prove that it has something indispensable to offer before we hand them our classrooms.*

In closing, the use of ICT in American schools appears to have presidential support through a pledge to connect every student to the Internet by the year 2000. Popular Science reported that, in a commencement address at MIT, the president said:

> *Until every child has a computer in the classroom and the skills to use it….until every student can tap the enormous resources of the Internet…until every high-tech company can find skilled workers to fill its high-tech jobs….America will miss the full promise of the information age.*

He is cited as saying "the choice is simple. We can extend opportunity today to all Americans or leave some behind."

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