

Critical Issue:

Technology: A Catalyst for Teaching and Learning in the Classroom

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ISSUE:

The interface between educational technology and science and mathematics instruction is integral and symbiotic. Few of the examples noted in the Glenn Commission report (National Commission on Mathematics and Science Teaching for the 21st Century, 2000) would be as advanced as they are without the use of technology:

Literacy in these areas [mathematics and science] affects the ability to understand weather and stock reports, develop a personal financial plan, or understand a doctor's advice. Taking advantage of mathematical and scientific information does not generally require an expert's grasp of those disciplines. But it does require a distinctive approach to analyzing information. We all have to be able to make accurate observations, develop conjectures, and test hypotheses: In short, we have to be familiar with a scientific approach. (p. 14)

Educational technology, especially computers and computer-related peripherals, have grown tremendously and have permeated all areas of our lives. It is incomprehensible that anyone today would argue that banks, hospitals, or any industry should use less technology. Most young people cannot understand arguments that schools should limit technology use. For them, use of the Internet, for example, plays a major role in their relationships with their friends, their families, and their schools. Teens and their parents generally think use of the Internet enhances the social life and academic work of teenagers:

The Internet is becoming an increasingly vital tool in our information society. More Americans are going online to conduct such day-to-day activities as education, business transactions, personal correspondence, research and information-gathering, and job searches. Each year, being digitally connected becomes ever more critical to economic and educational advancement and community participation. Now that a large number of Americans regularly use the Internet to conduct daily activities, people who lack access to these tools are at a growing disadvantage. Therefore, raising the level of digital inclusion by increasing the number of Americans using the technology tools of the digital age is a vitally important national goal. (U.S. Department of Commerce, Economics and Statistics Administration, & National Telecommunications and Information Administration. (2000, p. xv)

The very concept of the Internet would not be possible without technology. This is paralleled by the incredibly rapid growth of information that likely would not be possible without this technology. Research centers with no computers would arouse suspicion about the completeness, accuracy, and currency of their information because science and mathematics information grows daily and much of that new information can only be found through the use of technology. In fact, very few would argue with the statement that computers are essential to the work of professional scientists and mathematicians.

From the beginning of the computer age, educational researchers and practitioners have told us that for technology use to be successful in our schools it needed to be closely tied to school reform. Glennan and Melmed (1995) wrote: "Technology without reform is likely to have little value: widespread reform without technology is probably impossible" (pp. xix–xx.). The unavoidable conclusion is that successful improvement of technology, science, and mathematics education is of high importance to our future. In 2002, 100 high-tech executives met with President Bush to discuss the future of technology: They indicated that improving mathematics and science education ranked next to national security and broadband Internet access was one of the most important considerations for improving economic growth in their companies.

Given the vital role of technology in today's world, this Critical Issue will examine the value of effective technology use in classrooms with specific references to mathematics and science instruction, programs, and curricula. It will attempt to answer the following three questions that are essential to making technology use more effective in instruction :

What prevents educational researchers from giving us definitive answers about technology in the classroom that would satisfy both critics and advocates?

What does the best quantitative and qualitative research tell us about educational technology's effectiveness and the conditions and factors necessary for maximum effectiveness?

Why is educational technology important to the teaching and learning of mathematics and science and what are the important considerations and resources that make technology use more effective?

OVERVIEW:

Teaching is changing and, in many ways, becoming a more difficult job because of increasingly numerous contradictory expectations, including the following:

1. We are living in an age of information overload with the expectation that students will learn high-level skills such as how to access, evaluate, analyze, and synthesize vast quantities of information. At the same time, teachers are evaluated by their ability to have students pass tests that often give no value to these abilities.
2. Teachers are expected to teach students to solve complex problems that require knowledge necessary across many subject areas even as they are held accountable for the teaching and learning of isolated skills and information.
3. Teachers are expected to meet the needs of all students and move them toward fulfillment of their individual potential even as they are pressured to prepare students for maximum performance on high-stakes assessment tests that are the primary measure of student and school success.

Technology can actually assist with some of these expectations and make teachers—and their students—more successful. However, as the world becomes more complex—virtually year-to-year instead of the generation-to-generation pace of most of the last century—educational needs continue to shift from teaching and learning isolated skills and information within each content area, to teaching skills that enable students to solve complex problems across many areas. Educators must prepare for a technology-rich future and keep up with change by adopting effective strategies that infuse lessons with appropriate technologies. This makes a authentic assessment needs even more important: Assessments must keep pace with effective instructional technology use. All this while educators at every level, but teachers especially, actively pursue professional development that enables a lifelong exploration of ways to enhance the teaching and learning of science and mathematics and support science and mathematics education reform. The National Center for Education Statistics reports that there are virtually no differences in Internet access between poor schools and wealthier schools any more, as Internet access has steadily been increasing in public schools over time (Fox, 2005). Technology being infused into the schools is ongoing, unstoppable, and necessary. Thus, school use and access to new and current technologies is on the rise and more and more states have established technology standards for students, teachers, and administrators (Fox, 2005). Teachers have begun to use the Internet more frequently as a valuable tool in their instruction:

Seventy-seven percent of public schools had a majority of teachers who used the Internet for instruction during the 2003–04 school year, up from 54 percent in 1998–99 ... with 73 percent of high-poverty schools and 71 percent of high-minority schools having a majority of their teachers using the Internet for instruction. (Fox, 2005, p. 42)

On the other hand, the apparent growth of technology use is not always welcomed by critics who argue that schools should use less technology. For example, Oppenheimer (2003) in his book titled *The Flickering Mind: The False Promise of Technology in the Classroom* concluded that placing computers in the classroom has been almost "entirely wasteful." Other critics have written and spoken extensively of their beliefs that schools should not use technology for a variety of reasons ranging from creating social isolation to preventing students from learning critical basic skills. This apparent paradox of technology use inexorably spreading across society—homes, businesses large and small, libraries, government—as critics continue to challenge its use in schools is even more puzzling when students are asked how important they believe technology and especially the Internet is to their lives and their schoolwork. The Pew Internet and American Life project (Levin & Arafeh, 2002) found that teenagers use the Internet extensively. About 17 million students, ages 12–17, use the Internet to finding information for school research; that number represents 94 percent of the youth in that age bracket. According to the study, students are very positive about the use of the Internet to do their schoolwork:

[Students] complete their schoolwork more quickly; they are less likely to get stymied by material they don't understand; their papers and projects are more likely to draw upon up-to-date sources and state-of-the-art knowledge; and, they are better at juggling their school assignments and extracurricular activities when they use the Internet. (Levin & Arafeh, 2002, p. ii)

However, paradoxically student perceptions about the in-school uses of technology may be less positive, depending on several factors. One factor revealed in this study is student perception of insufficient teacher knowledge. Another factor students revealed is their disappointment in the lack of quality access and presence of excessive filtering systems that prevent them from accessing significant sites, especially those related to medical topics. They noted that while there were exceptions of positive and engaging uses of the Internet assigned by their teachers, they stated that Internet-related assignments were often of poor quality:

Students say that the not-so-engaging uses are the more typical of their assignments. Students repeatedly told us that the quality of their Internet-based assignments was poor and uninspiring. They want to be assigned more—and more

engaging—Internet activities that are relevant to their lives. Indeed, many students assert that this would significantly improve their attitude toward school and learning. (Levin & Arafeh, 2002, p. iv)

Out of school, students use the Internet and handheld devices as major tools to maintain and enhance their social life and to communicate with friends locally and even internationally.

Overall, managing the changes in teaching (which surround and permeate implementation of technology use in schools) means dealing with student, parent, and institutional high expectations in student learning of high-level skills and content specifics as well as success on high-stakes assessments that tend to ignore many of those otherwise valued skills.

What Prevents Educational Researchers from Giving Us Definitive Answers About Technology in the Classroom That Would Satisfy Both Critics and Advocates?

There are several reasons K–12 educational organizations continue to agonize about how much and in what ways technology use in schools is appropriate. Their concerns include the following:

- Some uses of technology may add value while some may become a distraction for students.
- Technology is only one variable among many others that also need to be addressed.
- Teacher competency in the use of technology is often problematic.
- Students and teachers have unclear, and often inconsistent, expectations of technology use.

In considering research on technology, Fulton (1998) in an essay titled "A Framework for Considering Technology Effectiveness" noted that the following caveats must be taken into account:

The technology keeps changing; as hardware and software evolve, new educational opportunities appear.

Educational technologies are used in classroom settings, which rarely provide optimal conditions for their use.

Research findings and results are often inappropriately generalized across grade levels, students, subject matter, types of technologies, and applications.

- The teacher is a key variable in technology implementation and effectiveness.
- Technology's impact on teachers and their practice should be considered as important as student effects because students move on but teachers remain to influence many generations of students (p. 1).

Meanwhile, the usually high value-added effects of classroom technology use have received more critical review than other educational tools. But too often both the praise and criticism of such technology use fails to consider the large and varied range of contexts found in classrooms. As Fulton (1998) also noted:

In other words, to ask if technology works is almost the equivalent of saying "Do textbooks work?" Yes, some textbooks "work," in some conditions, with some teachers, with some students, but these same textbooks may not "work" in another educational context. Clearly, the question of technology effectiveness requires us to be clear in what results we seek, how we measure success, and how we define effectiveness. (p. 1)

Although researchers' degree of agreement fluctuates, instructional technology is generally recognized as a powerful means to boost student achievement (Kulik, 2002; Waxman, Connell, & Gray, 2002). But for technology to work, curriculum and instructional methods need to be expanded to match the variety and rich learning options that these technologies are making possible. Educators also understand that technology itself has created tools that can assist. They realize that assistive technology is about using simple implements like a pen grip or overhead projector as well as sophisticated software and adaptive hardware, so each learner has an opportunity to achieve. They recognize that technology integration means using many technologies to enhance teaching, learning, and multisensory experiences, providing "a range of pathways for students at varying levels" (Ficklen & Muscara, 2001, p. 26).

Questions:

- Why is Educational Technology Important to the Teaching and Learning of Mathematics and Science?
- What are the Important Considerations and Resources That Make Technology Use More Effective?

Mathematics and science have suffered from the stereotype that only a few people can and in fact need to be highly proficient in science and mathematics. An equally unfortunate and false stereotype is that primarily white males have the capability to become scientists and mathematicians. Barton (2002) provides compelling statistics about why those perceptions need to be changed:

While the number of 18- to 24-year-olds will grow by 3 million by 2010 and offer possibilities of a fresh supply of scientists and engineers from our colleges and graduate schools, there is one striking fact about that population increase: only 3 in 10 will be White. (Among all 18- to 24-year-olds, the percentage of those who are White will decline from 66 to 62 percent). White students currently represent [a] disproportionately large share of degree recipients. Blacks, Hispanics, and American Indians—who are currently underrepresented in college and graduate school programs—will constitute almost 60 percent of the population increase over the next decade. And as pointed out above, only 3 or 4 percent of high school seniors from these subgroups currently reach the "proficient" level in mathematics. While the growth in the proportion of these minorities in the 18- to 24-year-old population is not dramatic, it does point toward need for greater effort to improve their educational achievement. Together these facts make it clear that meeting our nation's future economic needs will not be possible without improving the math and science achievement of underrepresented minorities. (p. 4) Meanwhile, the educational role of technology has grown

tremendously in several ways proving that technology use is undeniably capable of, and important for, helping teach content. As noted in NCTM (Suydam, 1990, as cited in Jarrett, 1998):

Today's technology can offer adolescents a bridge from concrete to abstract thinking, enabling them to observe and create multiple representations of mathematical ideas: numerically, graphically, and symbolically. For example, students can use geometric construction software to investigate the relationship between the circumference and diameter of a circle. They can measure several round objects and record the circumference and diameter (numerical representation). They can plot the values and estimate a "best fit" (graphical representation). Students can then determine the best fit equation (symbolic representation). Technology can also help teachers respond to students' diverse learning styles by creating rich environments that engage students' tactile, visual, and auditory senses. Finally, information technologies such as word processing, calculators, spreadsheet tools, and the Internet can enable middle-grade students to begin learning higher communication and problem solving skills—abilities that are essential to mathematical thinking. (pp. 4–5)

Educational technology is now widely valued for its ability to enhance one of the most significant intellectual developments for students: their emerging ability to think abstractly (Jarrett, 1998, p. 4).

One of the necessary characteristics of the effective use of technology is that it be used for authentic tasks. According to Means and Olson (1997, as cited in Jarrett, 1998), there are the following important considerations for fostering the authentic uses of technology:

- The technology supports student performance of complex tasks that are similar to those performed by adult professionals and/or fill a genuine need of the student.
- The technology is integrated into activities that are a core part of the classroom curriculum.

Technology is treated as a tool to help accomplish complex tasks (rather than as a subject of study for its own sake) that engage students in extended and cooperative learning experiences that involve multiple disciplines. (p. 14) Technology has been proved to accommodate learning styles and to be an effective motivator for students with specific learning needs. Furthermore, students working in collaborative-team-learning settings appear to function better when learning events are accompanied by technology use. In addition, technology also is important when used to provide distance-learning opportunities to students who otherwise would not have access to course offerings. Distance education is especially important to students in rural settings because many high school courses that are necessary prerequisites in universities, such as higher mathematics and science offerings, are less available because of the fewer numbers of students in smaller schools.

In contrast to the statement above supported by The National Center for Education Statistics (Fox, 2005) that there are virtually no differences in Internet access between poor schools and wealthier schools, equal access to technology—especially in families of high poverty—continues to be a problem. The National Center for Education Statistics (DeBell & Chapman, 2003) study reported that among the group of children and adolescents who access the Internet at only one location, 52 percent of those from families in poverty and 59 percent of those whose parents have not earned at least a high school credential do so at school. In comparison, 26 percent of those from families not in poverty and 39 percent of those with more highly educated parents do so only at school. This illustrates the role of schools in bridging the digital divide.

A reasonable conclusion is that classroom computers and other technology can play many instructional roles, from personal tutor and information source to data organizer and communication tool. So, it is important for teachers to consider how computers and other electronic technologies can enhance the learning experiences of students and increase their productivity. The primary conclusion of much of the research is that technology has considerable potential for increasing interest in, and improving the quality of, learning in science and mathematics classrooms. However, effective use of instructional technology is possible only if sufficient attention is given to the following: Curriculum uses.

- Instructional pedagogy used.
- Assessments used.
- Sufficiency of technology and access to the Internet.
- Ability of the teacher, especially, to model uses of technology.

IMPLEMENTATION PITFALLS:



Some researchers believe that there are so many barriers to successful implementation of effective technology use in U.S. schools, and they are so prevalent, that it is very difficult to isolate and measure just how much effective technology use is actually in place in the schools. Some generic reasons for the failure of educational change-and-reform efforts are important to note, reasons which may certainly apply to efforts to create effective technology use. Fullan and Stiegelbauer (1991) indicate the following reasons:

- The purpose is not made clear.

- The participants are not involved in the planning process.
- The appeal is based on personal reasons.
- The habit patterns of the work group are ignored.
- Communication regarding change is poor.
- There is fear of failure.
- Excessive work pressure is involved.
- The cost is too high, or the reward for making the change is seen as inadequate.
- The present situation seems satisfactory.
- There is a lack of respect and trust in the change initiator.
- Likewise, there are many factors that affect technology implementation, especially in urban schools (Means, Penuel, & Padilla, 2001, p. 197), including the following:
 - Lack of technology infrastructure.
 - Lack of technical support.
 - Teacher discomfort with technology.
 - Lack of high-quality digital content.
 - Lack of instructional vision for technology use.
 - The constraints of academic schedules and departmental structures.
 - Lack of student technology skills.
 - Low expectation of students.
 - Accountability pressures.

DIFFERENT POINTS OF VIEW:



Routinely, articles and books are published that continue to make the argument that schools use too much technology. Some critics attack technology use in schools for physiological, psychological, moral, and physical reasons, and those critics and their opinions may never change. However, most critics attack technology use because they believe it provides minimal value-added benefit to educational efforts. *Fool's gold: A critical look at computers in childhood* (Cordes & Miller, 2000), *Oversold and underused: Computers in the classroom* (Cuban, 2001), and *The Flickering Mind* (Oppenheimer, 2003) are three critiques that have received considerable attention as serious criticisms of technology use in schools.

The main criticism in all three of these books, and other critical articles as well, is that computers are not as cost effective as other interventions. They note the obsolescence factor of computers and the ongoing costs of upgrading both hardware and software. Some critics indicate a belief that many hardware and software companies purposely design products to become quickly obsolete and thus require updates that educators must buy. It is their belief that educational technology is too much in its infancy and not yet reliable enough for use by most students. Some critics such as Kirkpatrick and Cuban (1998) indicate that technology equipment requires extensive support structures that require districts to take money away from basic expenditures for other and better uses in the classroom. They believe this money should be invested in the arts, science laboratories, shops, and anything else that involves more hands-on ways of learning. Technology literacy, some believe, is highly overblown in its importance and that people who need to use technology will learn by using task applications that involve "real" work.

The criticism is especially strong for computer use by younger students. Some critics believe that with the exceptions of assistive technologies for students with special needs, students below the third grade should not use much, if any, technology. Other critics are concerned that technology reduces socialization opportunities. Some parents are concerned about the effect that children are gaining so much of their world knowledge from a virtual, rather than the real, world. Other critics are concerned that the sexual and violent content accessible on the Internet challenges or prevents character education necessary for development of moral citizens (Rifkin, 2000). Some critics think that technology use is a wasteful and negative use of scarce resources and give examples of visiting schools where uses of computers are actually making education worse. They note that in many cases, teachers use computers to entertain students with irrelevant and unconnected activities because it makes their teaching lives easier and not because it benefits students as they learn important content. Subsequently, several people have written very enlightening responses to such critics. Two articles that are especially informative are "Myths and Realities about Technology in K-12" by G. M. Kleiman (2000) and "Strip Mining for Gold: Research and Policy in Educational Technology—A Response to *Fool's Gold*" by D. H. Clements and J. Samara (2003). Kleiman (2000) indicated that there are realities to some of the criticisms but that many of the points of objection are due to poor implementation of technology. He noted:

The central theme underlying all these myths is that while modern technology has great potential to enhance teaching and learning, turning that potential into reality on a large scale is a complex, multifaceted task. The key determinant of our success will not be the number of computers purchased or cables installed, but rather how we

define educational visions, prepare and support teachers, design curriculum, address issues of equity, and respond to the rapidly changing world. As is always the case in efforts to improve K–12 education, simple, short-term solutions turn out to be illusions; long-term, carefully planned commitments are required. (p. 20)

No doubt, technology will always have critics. Some believe that technology reduces hands-on experience and student engagement in active participation. Others believe technology reduces important human contact. In the final analysis, one can conclude that identified uses of technology can have different critiques depending on one's personal values and perspectives of what is good and bad in education. The single most important factor for reducing criticism of technology use in instruction is to have teachers who are competent and knowledgeable about appropriate and effective use of technology to improve student learning.