Technology and Education : Current and Future Trends

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Why predict the future? More than an attempt at being Nostradamus, the value is in providing targets against which others may compare their thoughts and to stimulate efforts to either facilitate or inhibit possible futures implied by the predictions. As technology plays a larger role in education, any predictions concerning the future of education must include an analysis of technological trends. The purpose of this paper is to do just that: Analyze the trends in technology and how they relate to education, and then to extrapolate these trends in an attempt to predict the future of technology and education. Much of what is predicted in this paper might offend ardent supporters of our traditional educational system and a large portion of it will probably miss the target substantially. However, it will be clear that as technology is adopted into education, the end result will be change.

Introduction

Education Today

For over a century, education has remained largely unchanged. Classrooms full of students deferring to the wisdom of an all-knowing professor has, is, and many believe, will continue to be the accepted mode of instruction. Despite many technological advances and the introduction of new pedagogical concepts, the majority of today's classrooms continue to utilize this traditional mode. Educators have thrived in a bubble immune from advancements in technology, but the increasing rate of change of these advances now look to be threatening to burst this bubble.

The world is changing -- it is getting both smaller and bigger at the same time. Our world shrinks as technologies now allow us to communicate both synchronously and asynchronously with peers around the world. Conversely, the explosion of information now available to us expands our view of the world. As a result of the ability to communicate globally and the information explosion, education must change. Most educators might not want to change, but the change is coming -- it is a matter of when not if. The challenge is to prepare the children of today for a world that has yet to be created, for jobs yet to be invented, and for technologies yet undreamed. As we will see, the driving forces of Moore's Law, Metcalfe's Law, technology fusion, and a changing world economy are redefining the way our children need to be taught. The current teaching paradigm of the teacher as the possessor and transferor of information is shifting to a new paradigm of the

teacher as a facilitator or coach. This new teacher will provide contextual learning environments that engage students in collaborative activities that will require communications and access to information that only technology can provide.

It is no secret that education is slow to change, especially in incorporating new technologies. This is described by Jukes and McCain (1997) as paradigm paralysis, the delay or limit in our ability to understand and use new technology due to previous experiences. It takes new experiences to replace the old ones, and this simply takes time. Unfortunately, education can no longer take the time it wants. The trends in technology are creating a future that is arriving faster than education is preparing for it. We must therefore ask what are these trends and how will education adapt to them? To answer these questions, the techniques of H.G. Wells will be used. Wells, the father of futures studies, "had a gift for seeing how all the activities of humankind -- social, cultural, technological, economic, political -- fit together to produce a single past, and by extension a single future" (Wagar, 1993, pg. 52). First we will take a brief look at our past to formulate an understanding of the trends of today. This will be followed by a detailed analysis of these trends. Finally, we will peek into the crystal ball and predict the future of technology and education.

The Trends of Today

Computers and Moore's Law

In order to understand today's technological trends, it helps to take a look at how they have developed over the years. Even in education, computers have a long history. For example, the ENIAC, built at the University of Pennsylvania's Moore School of Electrical Engineering between 1944 and 1946, was the first large-scale general-purpose electronic computer (Goldschmidt & Akera, 1998). It weighed 30-tons, contained 19,000 vacuum tubes, 1,500 relays, and consumed almost 200 kilowatts of electrical power (Weik, 1961). Designed to calculate trajectory tables for new guns, the ENIAC failed on an average of every seven minutes, but when it worked it could compute 10-digit multiplication in 3/1000th of a second -- a huge accomplishment for its day (Jukes & McCain, 1997).

More recently, the 1980 model Cray supercomputer was the fastest machine of its day. It cost $12 million, weighed five tons, and consumed 150kW of electricity -- all this and it had only 8MB of RAM and operated at speed of 80 MHz (Jukes & McCain, 1997). By comparison, a used computer today with the same capabilities can be purchased for under $300.

Since the popularization of the desktop computer in the 1980s, we have become painfully aware of how quickly computers become outdated. Many of today's educators point to this trend in their argument against the use of computers. This trend of increased power at lower cost is likely to continue well into the next century and has popularly become known as Moore's Law, after Gordon Moore, the cofounder of Intel Corporation. In 1965 he suggested (half in jest) that technology doubled in processing power approximately every 18 months and at the same time the price for that technology declined by about 35% a year relative to this power. The accuracy of Mr. Moore's prediction has proven to be frighteningly accurate. The table below (Tab. 1) illustrates the effects of Moore's Law from 1984 to 1999, with some minor adjustments. In a 1993 speech, Randall Tobias, the Vice Chairman of AT&T, put Moore's Law in perspective when he said, "...if we had had similar gains in automotive technology, today you could buy a Lexus for about $2. It would travel at the speed of sound, and go 600 miles on a thimble of gas. It would be only three inches long...but easy to parallel park!" (pg. 244).

(Assumptions: Every 18 months RAM doubles in size, HD increase 275% in size, CPU speed increases 40%, and cost drops 10%).

Moore's Law			
1984	1990	1999	
RAM (in Megabytes)	0.13	2	131
HD (in Megabytes)	0.4	23	10000
CPU (in MHz)	10	51	411
Cost	$4,000.00	$2,600.00	$1,400.00

Table 1 - Moore's Law

Taking the reverse stance of education, business and industry have adopted the approach of staying up-to-date with technology. The current economy appears to support the notion that this approach is valid, yet the majority of our schools continue to adopt the approach of remaining several technological generations behind business and industry.

The Graphical Interface and Educational Resistance

> *I see no advantage whatsoever to the graphical user interface ...Bill Gates, 1981*

The graphical user interface was first developed by Xerox's Palo Alto Research Center. After a visit to this lab, Steve Jobs, the chairman of Apple Computers, bought the idea and named it Macintosh. "For many, this event has been heralded as the most significant conceptual breakthrough in the history of PCs" (Jukes & McCain, 1997). Eventually, even the recalcitrant Bill Gates adopted the graphical interface into his Windows operating system.

During the 1990s, the graphical interface environment has allowed the general public to use computers in a variety of ways never imagined possible. The skills in operating a computer have become much like those necessary to play a video game -- point there, click the button, and something happens! The generation of video game players, our youth, effectively has become the best audience for computers, yet educators resist using them.

Since the large-scale induction of computers into America's schools in the early 1980s, there has been reluctance of educators to implement them. Teachers can hardly be blamed for this reluctance. A major barrier has been a lack of a universal agreement on how teachers should be prepared to use the technology (Willis & Mehlinger, 1996). This is not cause to write off the personal computer for classroom use. In reference to preparing pre- and in-service teachers, Bull and Cooper (1997) believe, "it is important to be realistic about the time frame that will be required to accomplish this [integration of technology] in the depth that may be eventually desired" (pg. 101). In fact, the last 15 to 20 years might be viewed more as a time of courtship

between computers and K-12 educators. Clearly, in order for educators to adopt current technologies an emphasis must be placed on adequately preparing pre- and in-service teachers.

Telecommunications/Networks and Metcalfe's Law

As the power of the computer increases, so do the capabilities of communications media including glass fibers, copper wires, and wireless communication systems. For example, scientists at Fujitsu and other companies have demonstrated the capacity to send data over a single strand of glass the diameter of a human hair at a speed of one trillion bits per second (Thornburg, 1997). At this rate the entire Library of Congress could be transmitted in seconds (Molitor, 1998), or 70 million simultaneous voice conversations could be sent on a single fiber (Tobias, 1993). Conventional copper wires cannot compete with these rates of transmission, but by using an Asynchronous Digital Subscriber Line (ADSL) transmissions in excess of six million bits per second can be achieved. Many cable television providers are providing broadband services of up to ten million bits per second over copper wire systems as well. Much like the phenomenon with computer memory, as these speeds increase, the cost of using these services decreases. Take for example the consistent decrease in long distance telephone rates over the last few years; the ability to transmit enormous numbers of calls through one wire has driven prices down substantially.

The combination of better, cheaper computers and increased bandwidth has caused a boon in the network community (i.e. the Internet). Bob Metcalfe, inventor of the Ethernet, suggested that the power of a network increases proportionally by the square of the number of users. Over time this has become known as Metcalfe's Law. Like Moore's Law, Metcalfe's Law has played a major role in shaping the business world, and now it is beginning to affect education. Simply put, Metcalfe's Law states that the more people that are connected to a network, the more powerful that network becomes. As millions connect to the Internet, the Network of networks, the power of sharing information and ideas grows. Education is in the business of sharing information and ideas, making Metcalfe's Law a force that will play a major role in shaping the institution in the years ahead.

Internet and the Web

The merging of Moore's Law, Metcalfe's Law, and easy-to-use graphical interfaces form the foundation of the communication revolution we are now experiencing. The International Data Corporation (IDC) forecasts that 320 million people will be able to access the World Wide Web by 2002. In 1997, 78 million devices connected to the Web; by 2002 this number will increase to 515 million (WISTA, 1998). In 1996, the U.S. Postal Service delivered an astonishing 185 billion pieces of first class mail, yet in that same year the Internet handled about one trillion e-mail messages. Federal Communications Committee Chairman Reed Hunt has said, "The communication age is connected to the greatest revolution in the history of education since the invention of the printing press" (Thourburg, 1997).

Technology Fusion

Another event that will likely have a significant impact on education is technology fusion. Twenty years ago we saw sharp distinctions between computers, photos, publishing, TV/video, and telecommunications. Now the distinctions between these media are blurring (see Fig. 1 below). In

a few more years there will be virtually no distinction between them (Jukes & McCain, 1997) (Land & Portway, No Date). The result of this fusion is the manufacturing of computers that can perform all of the functions that not long ago needed separate devices. The Education Coalition (TEC) considers the merger of computing, television, printing and telecommunications as the most significant trend in education and technology. "Bringing them together results in the whole having greater impact than each individual part..." (Land & Portway).

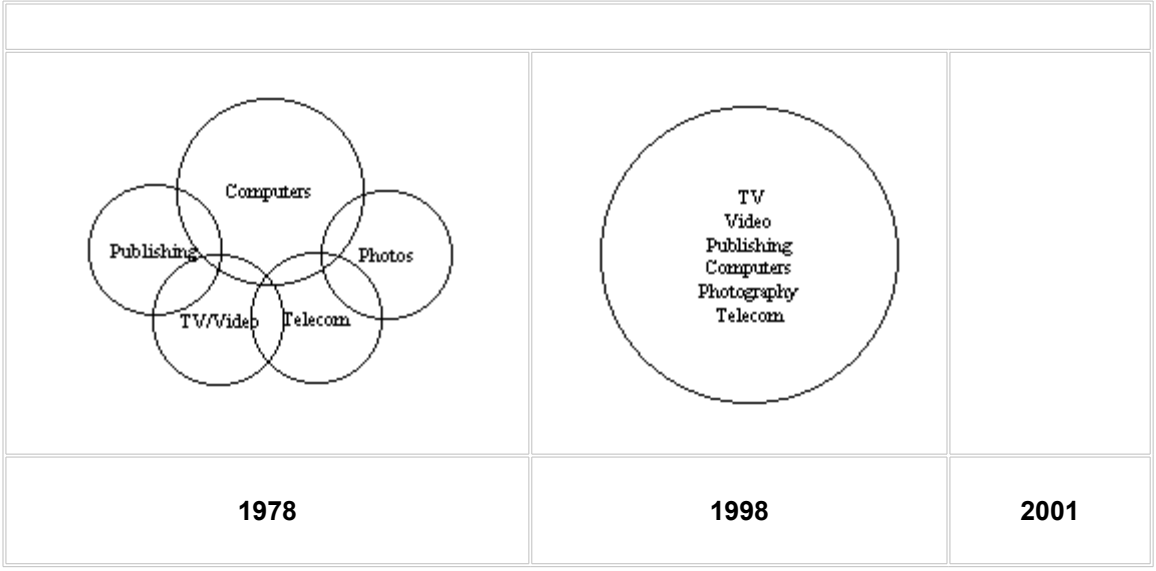

Figure 1 (adapted from Jukes, 1997)

Economy

If education is responsible for preparing its students to be contributing members to the world economy (it is the opinion of the author that this is a responsibility of education), we must consider what type of an economy these students will be entering. In October 1998, The World Information Technology and Services Alliance (WISTA) published a report entitled, Digital Planet, the Global Information Economy. WISTA commissioned International Data Corporation to perform this study which presents the broadest view of current levels of customer spending on information technology and communications ever assembled. The study concluded that spending on information and communications technology (ICT) is a critically important element of the worldwide economy. Below are some of the study's findings (WISTA, 1998):

- ICT was responsible for $1.8 trillion in spending in 1997.
- In 1997, ICT spending was nearly 40% larger than in 1992.
- ICT spending is growing 27% faster than the overall worldwide Gross Domestic Product.
- Spending on ICT is a key accelerator, catalyst, and multiplier of a wide variety of social and economic measures, including company and job growth.
- An average of 7,200 new tax-paying ICT companies have been added in the United States during each of the last five years.
- 380,000 "software and service" jobs have been added in the United States during the past five years.
- ICT increases overall economic activity.

With the world economy so intricately tied to information and communications technologies, the careers of today and tomorrow are directly related to these technologies. The Thornburg Center recently conducted a study of the 54 jobs identified by the U.S. Bureau of Labor Statistics as having the highest numerical growth between now and the year 2005. Of the 54 jobs, 46 required technological fluency, and none of the remaining eight paid more than double minimum wage (Thorburg, 1997). Technological fluency is more than technological literacy; it requires that an individual be as comfortable using technology as they are reading the newspaper. The lack of technologically fluent workers is already a problem. The Information Technology Association of America (ITAA) has warned that one out of ten jobs requiring information technology skills is going unfilled (Thornburg, 1997). Clearly, our educational system is failing to adequately prepare technologically fluent workers, so we must ask what does education need to do to address this problem?

The Role of Education

Being a Webmaster is one of today's hottest careers, yet five or six years ago Webmasters did not even exist. This is an example of how education must consider preparing students for jobs that have yet to be created. Alan Greenspan, the Chairman of the Federal Reserve Board, recently said (1997), "One of the most central dynamic forces [in the economy] is the accelerated expansion of computer and telecommunications technologies...clearly our educational institutions will continue to play an important role in preparing workers to meet these demands" (pg. 98). He also stated, "workers are facing the likelihood that they will need retooling during their careers...education is increasingly becoming a lifelong activity" (pg. 100). To prepare students to be lifelong learners requires a new approach to teaching, one in which students are taught how to learn on their own.

Unfortunately, we don't have to look hard to find teachers utilizing new technological tools to replicate old educational models. For example, most uses of distance education employ the same instructor delivering the same lecture to the same audience, only now the audience can be larger. This distance education model does nothing to address the concept of lifelong learning. This traditional model still places the student in a passive role, merely absorbing as much information as possible. Instead, more collaborative models of distance education could be employed. For example, The Center for Technology and Teacher Education at the University of Virginia uses live video connections with partner universities to bring together professors and students in a forum where all parties contribute and benefit from the collaborative learning experience. However, the overall dependence on the traditional instructional model dominates the majority of today's educational system.

Much of the failure to utilize technology in education today is, as Thornburg puts it, "the assumption that content [is] king...in a world of rapid information growth, it is context that matters...context is king" (in Thorburg, 1997, pg. 5). Thornburg advocates that rather than teach students a stockpile of facts to use "just in case" they might need them some day, that instead learning be put in context - i.e. master the ability to gather the appropriate facts and then creatively leverage those facts towards the learning objective. Teachers should create situations where the students are required to locate the facts and information specifically related to the context of the question at hand, and then to utilize that information effectively. An example is the Jasper Mathematics series created by the Vanderbilt University's Peabody College of Education. In these multimedia presentations, students are introduced to characters that are faced with a

mathematical dilemma that the students help the characters solve. Rather than having students learn facts "just in case" they might need them some day, the series promotes "just in time" learning; collaborative learning environments where groups of students find solutions to real-world scenarios. The 1995 Congressional Office of Technology Assessment report entitled Teachers & Technology: Making the Connection, encourages this type of teaching and explained how technology facilitates it (OTA, 1995, pg. 1-2):

"Using technology can change the way teachers teach. Some teachers use technology in 'teacher-centered' ways...On the other hand, some teachers use technology to support more student-centered approaches to instruction, so that students can conduct their own scientific inquiries and engage in collaborative activities while the teacher assumes the role of facilitator or coach."

When the rate of change inside an institution is less than the rate of change outside, the end is in site...

Jack Welch, CEO of General Electric

Right now, education is moving along at a snail's pace, while the world outside is speeding by at a supersonic rate. According to Fulton (1989, pg. 12), "Classrooms of today resemble their ancestors of 50 and 100 years ago much more closely than do today's hospital operating rooms, business offices, manufacturing plants, or scientific labs." If you put a doctor of 100 years ago in today's operating room, she would be lost, yet if you placed a teacher of 100 years ago into one of today's classrooms she wouldn't skip a beat. Does this mean that the end is in sight for education? The answer is YES, if your asking if it means the end of education as we know it today. Let us take a peek at what the future might look like.

The Future

Order Out of Chaos

Many factors or "wild cards" contribute to forecasting a possible future. Many futurists have likened these wild cards to the "butterfly effect" of chaos theory. The premise in the butterfly effect is that a butterfly flapping its wings in Singapore could cause a rippling effect that would eventually lead to a hurricane in the Caribbean. The premise behind chaos theory is that there can be order to chaos. The beauty of fractals is based upon this premise. Out of the chaos in today's world, we have found several trends: Moore's Law, Metcalfe's Law, technology fusion, and our technologically dependent world economy. We must finally ask where are these trends leading us and how might they impact education?

Future Technologies

If one lesson can be learned from our past it is to NOT put limits on what technology might someday produce. Assuming that ANYTHING is possible might be the best assumption. For example, consider what happens when we begin to extrapolate Moore's Law 10 and 20 years into the future (see Tab. 2 below)?

Moore's Law					
1984	1990	1999	2009	2020	
RAM (in Megabytes)	0.13	2	131	17000	2000000
HD (in Megabytes)	0.4	23	10000	12000000	14000000000
CPU (in MHz)	10	51	411	5500	75000
Cost	$4,000.00	$2,600.00	$1,400.00	$670.00	$320.00

Table 2 - Moore's Law Extrapolated

Gordon Moore believes that his Law will someday hit a wall: "Some time in the next several years we get to some finite limits, but not before we get through five generations" (in Kanellos, 1997). One study has shown that limitations could be reached by 2017. It does seem likely that we can assume growth to continue for several years to come. At current rates, by the time today's first and second graders graduate from high school, they will be using a computer that has 17,000 Megabytes of RAM, a HD of 12,000,000 Megabytes, a CPU speed of 5,500 Megahertz, and at a cost of less than $700. Extrapolating further is even more staggering.

We can hardly even begin to imagine what these computers will do. Metcalfe's Law combined with technology fusion should lead us to believe that we will have an increased reliance on a Global Digital Network, capable of sending and receiving any form of digital communication to and from anywhere in the world at any time. A global economy reliant on these emerging technologies is evidenced by current statistics. Still, we must ask what else is possible?

Fig. 2

In the very near future we will have a keyboardless computer. Voice software is already proving to be effective in its implementation and it seems only a matter of years before the keyboard will be removed from many if not most computer environments. Computers are shrinking in size and are now wearable. For under $5,000 Xybernaut sells a powerful speech-activated computer (see Fig. 2). Taking this one step farther, although more difficult to implement than originally anticipated, voice translation technologies will allow for nearly instantaneous communication with people of different languages (Molitor, 1998). The business and educational implications are staggering. For example, what if American students could instantly communicate with Chinese students? Would this change education?

Also possible are body-implant transceivers, all connected to the Global Digital Network, or medical breakthroughs such as video lens implants, which are already allowing individuals who were once blind to regain partial sight! For any Star Trek fans reading this paper, it might sound like we are slowly turning into the Borg (see Fig. 3). If this creature walked into your classroom, how would you react? The idea might seem ludicrous, but the idea of students walking into class with Sony Walkmans, pagers, and cell phones was recently considered ludicrous as well. The technology might someday make unbelievable things possible. It is therefore important for teachers to work closely with technology designers "to create a world that celebrates and promotes humanity through the judicious use of technology" (Graham, 1997, pg. 14).

Fig. 3 - The Borg
(Paramount Picture)

One must keep in mind that there are countless ways technology might develop during the next several decades. Knowing exactly what these developments will be or where they will lead is not only impossible, it is unimportant. It is the recognition of what is possible that educators must consider. Social implications could possibly be the hardest of all to predict, yet it will be education that many will look to in dealing with these implications. Adequately preparing for these implications will only occur if we look ahead, which ultimately requires us to ask, what do members of the educational community see when they look ahead?

The Future of Education: Futurists' Views

It is no secret that our educational system is slow to adopting innovations. The old adage, "the only constant in life is change," has rarely been applied to education. Gentry and Csete have stated, "educators are slow to recognize the need to develop a curriculum that will prepare the workforce for the demands they will face" (1990, pg. 25). Some would argue that change in education will continue to be a dream unrealized well into the new millennium, but many opinions run contrary to this argument.

In 1996, the American Association of School Administrators (AASA) brought together 55 advisors from various fields, including education, business, government, psychology, sociology, anthropology, and demography to study the future of education. A short summary of these findings is (Ulchida, 1996):

- Students need to be skilled in accessing the vast array of information available through advanced technology and be able to process the information.
- Students must know how to use computers and be familiar with various types of technology.
- Schools must incorporate "marketplace" technologies and ensure that new and emerging technologies are incorporated into the school program.

If an association of school administrators believes emerging technologies need to be incorporated into school programs then we can expect action on the subject.

A consistent point brought up by most futurists is the need to provide education to both children and adults. The Special Libraries Association (SLA) believes that schools will become around-the-clock facilities. The academic day will stretch to seven hours for children; adults will work a 32-hour week and prepare for their next job in the remaining hours. The SLA believes that new technologies will greatly enhance these educational opportunities with job simulation stations, telecommunications course-work (distance education), 3-D graphics, and artificial intelligence making the largest contributions. The driving force behind educational reform will come from the new information economy's call for technologically fluent workers. Government will place more emphasis on the outcomes of public education (for example, America 2000). Improved pedagogy will revolutionize learning; learning environments will become less important as individuals will learn more on their own. Computer-supported approaches to learning will allow for more content-specific material to be learned. (Cetrone & Davies, 1994).

Gentry and Csete (1990) have also written that pressures from business, industry, and government will "force the educational establishment to better prepare graduates for the workplace" (pg. 27). Several of the points they mentioned were that:

- Increased access to electronically delivered instruction will provide new channels of instruction developed independently of traditional educational systems.
- Artificial intelligence will have an increased role in education; as technology becomes easier to use, more educators will become adopters.
- Technology-capable students will demand the adoption of technology; independent learning skills (lifelong learning) will need to be supported.
- People conforming to technology will shift to technology fitting the diversity of the people using it.

Jukes and McCain (1997) of the Thornbur Center offer insight into the future of technology and education. Both see education's role as being similar to that of a quarterback on a football team: "A quarterback must be a futurist -- throwing the ball not to where the receiver is, but to where the receiver is going to be. It's much the same with technology. We need to be looking ahead 3, 4, even 5 generations down the road." Jukes, McCain, and David Thornburg advocate a new educational paradigm that shifts curriculum from content-based to process-based. Juke's and McCain's message is that educators need to change their mindset quickly, "or the market will find its educational experiences elsewhere" (1997). These experiences found elsewhere are already evidenced in increased home school numbers and support for school vouchers.

A 1997 study performed by the National Home Education Research Institute showed that there are approximately 1.23 million American children being taught at home. Home school students collectively outnumber the individual statewide public school enrollments in each of 41 states. On average, home schoolers out perform their public school counterparts by a minimum of 30 percentile points across all subjects. The study further shows that family income, parental education, gender and minority differences have no impact on the success of home school student performance. Also, the amount spent per student is staggeringly different: $546/student for home school versus $5,325/student for public schools. The study shows that nearly 84% of home school children use a computer in their education, compared to the national average of 26% (Ray, 1997).

School vouchers appear to be another factor that might create a larger private market for education. Initiatives in California and Florida have already shown that vouchers are gaining support among the American public.

Conclusion: The Author's Views

Experts from all fields, including education, business, and government agree that we have moved into the information age. As much as 97% of the world's knowledge will be accumulated over one person's lifetime (Molitor, 1998). Against statistics like this, teaching students a host of facts "just in case" they need them later on in life is a fruitless effort. The ability to find and use facts as they are needed becomes the skill that will enable students to become lifelong learners. The roll of education is no longer to provide educational opportunities through early adulthood, but to provide the scaffolding necessary to support individuals and families from all walks of life, throughout their entire lives. In order to prevent a further widening between the upper and lower classes, it will become increasingly important for educational institutions to provide this support by providing weeknight and weekend adult classes focused on emerging technologies.

Very soon we can look for interactive video technologies to allow parents to play a more active role in their children's education (e.g. watching a class presentation via online video). Schools that actively pursue such avenues will be in great demand. School days will grow to seven hours in length to provide more instruction and to meet the needs of dual income families. As more states pass school voucher initiatives, a greater dependency upon private education will result. Schools will compete to hire teachers, raising teacher salaries. Dissatisfaction with public education and national and statewide acceptance of school vouchers will cause the private and home schooling markets to grow well into the next century.

The effects of Moore's Law, Metcalfe's Law, and technology fusion will produce a variety of hand-held and wearable computers that will be connected to a worldwide digital network. Technology fusion and a changing world economy will place new demands upon education. The teacher's role will shift from that of the transmitter of facts, to a facilitator, coaching students in how to find and use facts specific to a particular context.

I could continue with some loftier predictions, but to do so would only trivialize what I have predicted. As mentioned earlier, knowing exactly what happens in our future is not important. It is important that educators have a sense of where the world is headed. Only then will they be able to adequately prepare current and future students to thrive in this ever-changing world. We must

always keep in mind that a good driver doesn't watch the car's hood while they are motoring down the road. Instead, a good driver carefully watches the road ahead, looking for the obstacles and challenges that lie before them. It is time that education quit watching its hood and start looking at the road ahead.

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