UNDERSTANDING HEPHAISTOS:
TOWARD THE APPROPRIATE USE OF EDUCATIONAL TECHNOLOGY

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INTRODUCTION: THE PROBLEM OF COMPUTERS IN CLASSROOMS

In 1984 Douglas Sloan opened a conference on computers in education at Teachers College with the following words:

> "The computer offers potential for human betterment, and at the same time is fraught with great dangers to the human being; that neither the potential can be truly realized, nor the dangers avoided, without careful, far-reaching, critical questions being asked about the computer in education; and that American educators in general have been almost totally remiss in their responsibility to appraise and pursue these critical questions.
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> Extolling the computer as a boon to critical thinking, professional educators by and large have been conspicuously uncritical about the computer itself. Scrambling to lead the van of the computer communications revolutions in education, American educators have made no concerted effort to ask at what level, for what purposes, and in what ways the computer is educationally appropriate and inappropriate, in what ways and to whom—and to whom we can count on its being beneficial or harmful. The overall picture has been one, instead, of educators vying to outdo one another in thinking of new ways to use the computer in all manners and at every level of education possible. Professional responsibility demands more."[1]

Responsibility as educators, responsibility as parents, responsibility simply as people who care about youth demands more. Unfortunately, little progress has occurred since Dr. Sloan spoke those words fourteen years ago. The promises and practices of educational technology are, generally, still accepted uncritically. We may be, however, at the beginning of a time when scrutiny of educational technology moves from the fringe to the mainstream.

Two recent studies raise serious questions concerning the effectiveness of computers in education and the effect of the Internet on social and emotional aspects of life. The first, a large study by the Educational Testing Service (ETS), demonstrates that there are no real advantages to classroom use of computers for mathematics instruction.[2] In fact, for fourth graders, math achievement actually goes down with increased use of computers. The second study, commissioned by the computer industry and performed by a group of researchers at Carnegie Mellon University, found that use of the Internet increases the incidence of depression among users.[3] Both studies have come under attack from computer-related industries and boosters of educational technology, but the studies stand nonetheless. They are, moreover, in agreement with earlier research on the questionable effectiveness of technology in education.

Sylvia Charp, an advocate of computers in education, surveyed the thirty year history of computers in education and depicts, candidly, a history of failure.[4] Time after time, bright people with extraordinary amounts of money and good intentions have tested computers in educational settings and produced, essentially, no positive results. Small and anecdotal instances sometimes suggest individual benefits, but, on the whole, Charp paints a sobering picture. She remains cautiously optimistic about the future, but this is her profession, after all.

The thirty year history that Charp investigates includes LOGO, the computer language designed by Seymour Papert of MIT in the early 1980s.[5] LOGO was intended to transform the learning experience, but, according to Alan Kay[6] and to my experience with students, LOGO mystified both teachers and students. An informal survey of my Amherst College students showed that only two of them had used LOGO, and neither of them understands its value to this day. LOGO may have been a brilliant and imaginative way of using computers in education, but it was lost on the teachers, it was lost on the students, and ultimately it disappeared from the landscape. Similarly, Apple's "Classrooms of Tomorrow" have virtually evaporated; not, however, before consuming vast resources of time and money.

Recently, the media have started to air concerns about the tradeoffs inherent in our infatuation with educational technology. Education Week's technology report admitted that, while "unprecedented support for school technology is spurring an investment of billions of dollars, a lack of research and a dearth of data mean the payoff is unclear."[7] Or, in another article, "many educators are banking on the belief that technology improves student achievement."[8] Although research shows mixed results at best, we might add. A report in CEO Forum concludes that, to date, there has been little conclusive research that measures or demonstrates the full benefits of technology on the processes of teaching and learning.[9] Again, we have invested huge sums of money with very little knowledge to guide our investments and very little proof of the benefits, if any, of computer technology in our classrooms. The primary recommendation of the Panel on Educational Technology, part of the President's Committee of Advisors on Science and Technology, is for a huge increase—to 1.5 billion dollars—in careful research into the effectiveness of educational technology.[10]

RESEARCH SHOWS...

To date, most of the research on educational technology has been on computer assisted instruction (CAI). This is basically drilled practice: Test; drill; test again. It is the most pedestrian form of instruction, glorified flash-cards on the computer. The computer can track performance and the graphical display can be made somewhat more appealing than standard flash-cards, but such software hardly constitutes an educational revolution. Studies of these kinds of applications show that, at great cost, they do seem to increase the performance of the students; not dramatically, but measurably. Educational specialists, however, do not hold such "drill and kill," as it is called by some skeptics, to be a motive reason for including educational technology in classrooms. There are much more ambitious enterprises afoot, and here the data is more ambiguous; it is not clear at all that more sophisticated uses of the computer are worthwhile. After thirty years, we are left with many inconclusive studies, untrustworthy anecdotal evidence and no dramatic increase in achievement or performance in classrooms.

Further, according to Richard Lookatch, the studies that do show benefits to computer technology in classrooms often suffer from fundamental flaws, such as the so-called Type I error.[11] That is, the studies are conducted in such a way that the benefit is statistically meaningless, and may not even exist. For example, a computer group may spend a million dollars developing a piece of exciting, intelligent educational software. A study then compares that software product with a print product, off-the-shelf, that was put together for a few thousand dollars. The study is not comparing the technologies, of course, it is comparing investments.

A USEFUL TOOL

Putting aside Internet and research use for the moment, let us observe academic computer use in homes, in classrooms and in libraries. Studies show that, at least in high schools, the primary use is for word processing. Colleges often add a limited use of graphing and spreadsheets. For those Amherst College students unfamiliar with spreadsheets, we teach this application in a couple of lab periods. Furthermore, just where we might hope for true computer virtuosity, in programming, we find instead that the study of programming is declining.[12] Fewer computer science majors graduate from American universities today than did several years ago. In general, we have become less and less interested in understanding the computer and more and more interested in it as a commodity. Computers are used, then, not as we might have expected, not as we might have hoped, but in ways that should certainly deflate our exaggerated expectations. The computer is a useful tool, not a revolution in learning.

My intention is not to snipe at technology. It is imperative, however, that we evaluate educational technology in a sober, responsible, professional manner. I am a physicist with a strange penchant for technology. As a teen, I lived under the hood of my '55 Chevy. I have interfaced computers to laser experiments, I have worked with computers from the bottom up. I programmed an empty PDP8 composed of only logic circuits and ferrite memory beads. I first loaded a binary instruction set using toggle switches which "taught" it to read a paper tape. From the paper tape I taught it to read a keyboard, and then from the keyboard taught it to do something useful. In the process, I realized that the computer is, fundamentally, a mechanical device. On the other hand, I saw what power it can have. I want that power to serve us, not to dominate us.

A VERY EXPENSIVE TOOL

The issue of computers in classrooms, however, is an economic subject as well as an academic one. Educational technology is expensive. In the 1995-96 school year, four billion tax dollars purchased hardware, software, maintenance and professional development for computers and their use in schools.[13] Given the 44 million school children in the U.S., that is ninety dollars per child. Projections ask for a basic minimum of 13 billion dollars for computers in classrooms, almost four times the '95-'96 amount, or $350 per child. This may not seem like much when we spend, on average, $5600 per child in public school, but this is a minimum projection.[14]

Henry Becker, professor of education at the University of California, Irvine, and a member of the President's Panel on Educational Technology, produced what he considered to be a realistic estimate of what educators believe a decent integrated technology in the classroom would cost, an estimate that includes the cost of teacher training.[15] Personnel costs alone would be $1375 per year, per child. The cost per student for hardware, software and maintenance would be $556. These costs total almost $2000 per child, an increase of 33-40% over the total present expenditures on education, or 88 billion dollars per year. If we were assured that this tremendous increase would make a significant difference, we would certainly pursue it for the good of our children. The data are so inconclusive, however, and the history is so uncertain that we simply do not have the right to spend so much of taxpayers' money for such uncertain gain.

Comparable experiences in businesses should give us pause. Computers were and are still expected by some to result in huge increases in productivity, but, generally speaking, they have not. In the last two or three years many studies, including one reported in an article by two

Princeton economists,[16] have examined the failure of computers to increase productivity. There are, of course, special, isolated instances in which computers have contributed to improvements in productivity. Across the business world, however, there has been no increase, and, in some cases, there has even been a decrease in productivity associated with the introduction of computers.

Examining previous technological optimism may also help us to be more cautious and more sophisticated in the ways in which we bring this technology into our classrooms. In 1922, Thomas Edison wrote, "I believe that the motion picture is destined to revolutionize our educational system, and that in a few years it will supplant largely, if not entirely, the use of textbooks."[17] Film and video have found a more or less appropriate place in our classrooms, but the technology that they represent has hardly lived up to Edison's expectations.

Similarly, in 1984, Seymour Papert claimed that, because of the computer, there would not be schools in the future: "The computer will blow up the schools."[18] Like Edison, Papert imagined that new technology would lead to a complete restructuring, reimagination, and devastation of the conventional curriculum and conventional ways of teaching. This simply has not happened.

Much of the present hyperbole speaks of a "third industrial revolution," the knowledge revolution. The President's report, for example, states, "In particular, it is widely believed that a

> continuing acceleration of the pace of technological innovation, among other factors, will result in more frequent changes in the knowledge and skills that workers will need if they are to play high level roles within the global economy of the twenty-first century."[19]

Frank Withrow, Director of Learning Technologies at the Council of Chief State School Officers, says that the U.S. work force does not need knowers, it needs learners. Word processing, spreadsheets and database management, obviously, have little to do with becoming learners. If we only educate our children with such utilitarian computer functions, we are educating for a world of clerks, not "knowledge workers." This, again, is no revolution in education.

APPROPRIATE USE

To use these expensive tools appropriately, we must alter our thinking regarding at least two important points. First, computers need to be embedded in an age-appropriate learning environment. To use computers in classrooms, we must have clear goals for their use and we must consider the cognitive and emotional development of our students. I confess that I have not seen a substantial, appropriate use for computers in education before the sixth grade. Only around sixth or seventh grade, even among very bright and motivated students, are students generally developed sufficiently to make their use in education worthwhile.

Second, we need soberly to cut through the rhetoric that surrounds educational technology. The third industrial revolution, the knowledge revolution, if it exists, will not be found in a word processor, a spreadsheet, a power-point presentation, nor even the Internet. These are or will soon become library resources, tools, like hammers and nails, books and videos. We do not educate our children, however, simply to use tools. We educate thinkers, artists, workers and managers who posses creativity, resourcefulness, independence, good judgment and self-confidence. We aim to create life-long learners who are truly flexible in thought and mind, who are aware that they are embedded in and responsible to a society and a planet. Tools should serve these ends. As currently deployed, the computer does not.

THE TECHNOLOGICAL SUBLIME

In the face of missing evidence and serious concerns, technology still has a powerful allure. Why? David Nye, among others, calls it the allure of the "technological sublime."[20] He documents the similarities between our connection to the sublime through nature and our connection to the sublime through technology. He shows that the technological sublime harks back to the eighteenth century and the natural sublime of the Romantics. We stand before the great natural wonder of the Grand Canyon, for example, and experience something larger than ourselves, something that links us to the transcendent. This experience, according to Edmund Burke, is an experience of the sublime.[21] When we approach the Grand Canyon, we are enacting a ritual, enacted also by millions of others, seeking a kind of revelation. In America, rituals such as this have been an important part of the formation of our national psyche.

When my children were in fifth or sixth grade, we traveled to see the Grand Canyon and other national parks, but we also went to see industrial America. I had yet to read about the technological sublime, but I wanted to show my children America's great factories. I wanted to show them mines. As a physics professor and research scientist, I was able to obtain access that is unfortunately denied to most people, disingenuously, for reasons of health and safety. In Canton, Ohio, at the LTV-Republic steel mills we saw several huge carbon arc furnaces lined up into the distance, with overhead cranes as big as a lecture hall, and ladles of molten steel pouring, and sparks flying. Electricity throbbing through the discharge created the melt, the ground vibrated, and huge electrical cables swayed. We felt that all of the power of civilization was somehow thrust down into these huge vats of molten steel. It was an overwhelming, awesome experience of the technological sublime.

The experience of the technological sublime was known as well to Americans in the nineteenth century. Ralph Waldo Emerson visited the Lowell, MA, textile mills to lecture to the thousands of women who operated them, and he concluded that somehow technology could contribute to our salvation. Charles Dickens, who was no friend of the mills in Britain, favored American technology of the time. Andrew Jackson was also enchanted by the Lowell mills; he had them turned on so he could see them in operation, although they had been closed in honor of his visit. Walt Whitman, in a wheelchair, asked to be left in front of the Corliss steam engine at the Philadelphia Exposition of 1876. The steam engine was three stories high, and it operated just slowly enough that one could see and follow all the moving parts. It is said that Whitman sat there for half an hour in silence, meditating. Henry Adams wrote, in praise of technology, "The Dynamo and The Virgin."[22] The Virgin Mary motivated people to build the great cathedrals of Europe, he argued, and the electric generator, the dynamo, motivated modern Americans.

"WHERE THE DANGER IS…"

Technology can connect us to something larger than ourselves, but it also endangers us.

Physical danger is present in many of our manufacturing processes, but, more important, technology is also mentally and emotionally dangerous. This is nothing new.

The relationship between technology and the sacred has always been ambivalent. Hephaistos, the Greek god of craft, the smith, provides an archetype of this ambivalence. When Hephaistos was born to Zeus and Hera, lame and crippled, he was thrown off Mt. Olympus. He fell all day, landing on the volcanic island of Lemnos. There he learned to handle fire and he became a smith. He was the laughingstock of the Greek gods, yet he was the only one of the gods able to work in the physical world. When Zeus wanted to catch Prometheus, he had Hephaistos fashion an automaton, Pandora. Pandora had not only her infamous box, but also chains to bind Prometheus—the fire-bringer, incidentally—to the mountains of the Caucasus. Many other cultures also have a celestial smith. In the Kalevala, for example, the smith Ilmarinen forges a sampo, a magic mill, in order to win the hand of his bride. Further, these figures are marginalized, disfigured outcasts. In the Old Testament, the name of Cain is etymologically connected to the word "smith," and Cain is marked and cast out. According to anthropologists, the Mande blacksmiths in Africa have to live on the edge of town. The chief who wishes to talk with a blacksmith travels to the smith's abode at the edge of town, and speaks with him flatteringly and as an equal. Yet, as soon as he leaves the smithy, he has nothing good to say about the blacksmith.[23] His relationship with the smith is similar to that of Zeus and his attitude toward Hephaistos.

These technologists are embedded in a mythic and sacred universe, and blacksmiths, heirs of the mythic smiths, often understand what they do to be embedded in a world of mythic images. A Mande smith who wishes to mine ore performs his ritual ablutions, purifies himself, fasts, practices abstinence, then travels with fellow smiths. No one else can accompany them. He goes into the earth—that is to say, into the mother—and performs an abortion. What we would call ore, the Egyptians, for example, called ku-bu, embryos. The smith mines metals that are not yet ripe in the earth and then ripens them, out of time, in the fire. They mature from the ore, which looks like mere rock, to copper or to iron, through the dangerous craft of the fire. According to Eliade, smelting can be thought of as an embryogenesis of metals.[24] There are clear parallels here with the dangerous work of the men in the Canton, Ohio, steel mills.

EMBEDDING THE COMPUTER

Both Martin Heidegger, in The Question Concerning Technology and Other Essays,[25] and Albert Borgmann, in Technology and the Character of Contemporary Life,[26] aim to understand technology not as a superficial phenomenon, but in its more profound implications. Heidegger, through a series of questions, attempts to establish a path to the essence of technology. Along the way he finds the consummate danger of technology. The sorcerer's apprentice naively plays with magic of the master. Because he has not penetrated to the heart of the thing itself, however, he cannot control it, and his play wreaks havoc. The key transformation for Heidegger is the establishment of a mature and free relationship to technology. Technology must become our servant, not our master. Only then will technology take its rightful place in our individual lives and in our society.

Borgmann examines the promise of technology, a promise that seduces us with notions of an easier, less expensive life. He points out, for example, that when we create heat as a commodity, a commodity produced through advanced technology, all of the burdens connected with heating disappear. With the removal of these burdens, the heat as a product is decontextualized, cut off from the network of connections that embed it in a social framework. The production of heat is abstracted from the lives of individuals and from the life of the community. Borgmann calls this change the abstraction from a "thing" to a "device." Things have social connections, are multi-dimensional; devices are essentially one-dimensional and divorced from social connection. Central heating, controlled by a computer chip and programmed with push buttons, replaces the socially and environmentally important tasks of chopping, splitting, stacking wood, loading and cleaning the stove—only to heat one room. These tasks, while they can be performed by one person, often involve a community and a family. I discuss life with the man who delivers my wood, and my children help with chores related to our wood stove. Central heat has replaced industries that used to organize the lives of many people. More important, perhaps, the technology of heat has become virtually invisible to our thought and to our actions.

Educational technology, like central heating, raises important social and environmental questions. On the one hand, computers may—and, as we have seen, this is still at best only a possibility—teach faster, better, more accurately and more economically than do fallible, demanding teachers. We should be aware, however, of what will change as we give our classrooms and children over to increasingly pervasive educational technology. Relationships with teachers, parents, other children, nature, books, an entire life-world will alter. This life-world, I argue, is absolutely central to the project of the education of young children. To educate with unfeeling computers cannot help but make our children more estranged from the world around them. To educate them among caring human beings cannot help but make our children more humane. Any technology, from the simplest to the most advanced, will, of its nature, change or even threaten the primary relationships of children to the world around them. The more powerful the technology that we introduce, the more profound those changes can be. We must be wise in our use of technology if we are to sense and elude the dangers that always attend it.

PENETRATING TECHNOLOGY

There are, of course, important and age-appropriate uses for computers in education. When children begin to use the library for research projects, it is important that they have the best resources we can give them. Many of these are currently available through the Internet, but the best ones are expensive. E-mail can also be useful for older students, perhaps from the middle grades on. Some drill and practice may be well handled by computers. On the other hand, there is no substitute for actual experience with other human beings. Learning foreign language vocabulary from a computer is no substitute for a living experience of a foreign language, whether from a teacher, through a neighbor down the block, or through an exchange with a family in another country.

Applications for computers in classrooms all aim to help. They are there to make learning easier. There are times, however, when it is educationally essential that we make life hard. Students in my physics classes solve equations with a calculator and repeatedly get answers that are wildly wrong, many orders of magnitude wrong. They are seduced by the ease of pushing buttons on the device. If they solve a problem or two by hand, perhaps a couple of different ways, that hard route will teach them the meaning of the numbers that they are manipulating. Experience, tough experience, is a necessary teacher. Having first won knowledge the hard way, it may well be appropriate to pursue the easier but more abstract and distant methods offered by technology.

Particularly with regard to computers, we can offer an opportunity for good, hard, learning by asking students to understand the computer from the ground up. This is what I did with my twelve year-old son. I told him that, if he wanted to play a computer game, he should write one himself. Using machine language, he wrote a program that translated from base ten to base sixteen, then he learned a little BASIC, enough to write a simple game. This experience made the computer transparent for his thinking. It brought home concretely the way computers work and the realization that computers serve us, not the other way around. Not every middle school student's father is a physics professor, of course, but nothing fundamentally important to understanding a computer is so complicated that it cannot be taught in high school.

CONCLUSION: HEPHAISTOS' WIFE

Technology is and always will be double-edged. It will help us and it will endanger us. It will serve us if we understand it and understand the ramifications of its use, and it will enslave us if we do not. In this sense, we are all like Hephaistos. We are all like the Mande blacksmiths and like Cain. Technology can, if we thoughtfully master the sensual, connect us to the sublime. If we thoughtlessly indulge the sensual, however, technology can ensnare us in its mechanism. Hölderlin, quoted by Heidegger, says, "but where the danger is, grows the saving power also."[27] To believe that we can avoid danger, he claims, is naive. Rather, we have to find the resources in ourselves to meet every challenge. Having done so we are well rewarded: You may recall that the wife of Hephaistos is Aphrodite. The most beautiful of all the Greek goddesses is married to the crippled, fallen god. We of the twentieth century are fallen figures, technologists all, living close to the fire. We can, however, seek for a true and fruitful union with our other half, the archetypal feminine. In the words of Dostoyevsky's Idiot, we will be saved by beauty. The education of our children requires not only that we claim as master the technology of Hephaistos, but that we develop also the love of Aphrodite, of beauty.

NOTES

[1] Sloan, D., Ed. (1984). The Computer in Education: A Critical Perspective. Teachers College Press: New York.

[2] "Does It Compute: The Relationship Between Educational Technology and Student Achievement in Mathematics." September 1998. http://www.ets.org/research/pic.

[3] R. Kraut, et al. (1998) "Internet Paradox: A Social Technology That Reduces Social Involvement and Psychological Well-Being?" In American Psychologist, 53, 9. http://homenet.andrew.cmu.edu/progress/research.html

[4] Charp, S. (1997). Technological Horizons in Education, 24,11, 8.

[5] see Papert, S. (1980) Mind-Storms: Children, Computers and Powerful Ideas. New York: Basic Books.

[6] Kay, A. (1997). "The Computer in Education: Seeking the Human Essentials." Lecture, Teachers College, Columbia University: New York.

[7] Trotter, T. (1997). "Taking technology's measure." In Education Week. http://www.edweek.org/sreports/tc/intros/in-n.htm

[8] ibid; Viadero, D.

[9] "Report 97, Future Research." In CEO Forum. http://www.ceoforum.org/report97/future.html

[10] President's Committee of Advisors on Science and Technology, Panel on Educational Technology (1997) "Report to the President on the Use of Technology to Strengthen K-12 Education in the United States." March.

[11] Lookatch, R. (1995) "The Strange But True Story of Multimedia and the Type I Error." In Technos, 4, 2, summer.

[12] "Computers and Classrooms: The Status of Technology in U.S. Schools." Princeton: Educational Testing Service. http://www.ets.org/research

[13] President's Committee. "Report to the President." 6.1

[14] ibid., 6.2.

[15] ibid., 6.2.

[16] Blinder, A. and R. Quandt (1997) "The Computer and the Economy." In Atlantic Monthly, 281, 6, December.

[17] Quoted in ETS. "Computers and Classrooms"

[18] Quoted in ETS. "Computers and Classrooms"

[19] Report to the President, 2.1.

[20] Nye, D. (1994). The American Technological Sublime. Cambridge, MA: MIT Press.

[21] ibid., 6.

[22] Adams, H. (1918). "The Dynamo and the Virgin." In The Education of Henry Adams. Boston: Houghton-Mifflin.

[23] McNaughton, P. (1988). The Mande Blacksmiths: Knowledge, Power and Art in West Africa. Bloomington: Indiana University Press.

[24] Eliade, M. (1962). The Forge and the Crucible. Chicago: University of Chicago Press.

[25] Heidegger, M. (1977). The Question Concerning Technology and Other Essays. New York: Garland Pub.

[26] Borgmann, A. (1984). Technology and the Character of Contemporary Life: A Philosophical Inquiry. Chicago: University of Chicago Press.

[27] Heidegger, The Question Concerning Technology, 28.