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Presidential Address

Future Shock: Education in the Information Age

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A colleague asked me some time ago if I thought technology, specifically the Internet, would do away with higher education as we know it. Would this new technology—with its ability to organize and present information faster than we can even think of the questions, at distances sometimes not spanned reliably by telephone—create that fundamental change, that shift of paradigms referred to by Kuhn? He asked me this question because he was genuinely concerned on a number of levels. He also knew that I was into technology, having spent the last decade studying, thinking, and experimenting with new technologies in education and educational research.

On the most primary level he wondered if he could learn, change, and adapt to the new technologies, and so be able to remain a contributing member of the faculty. He didn't want to be a dinosaur, made extinct by the comet of micro-electronics. He was worried about whether he could still contribute, still make a difference, still even be able to interact with others in his field! Being tenured, he wasn't worried about losing his job, although he was worried about being marginalized by his younger and more technically literate peers. How could he be the "senior scholar," the "elder statesman," if what he knew no longer mattered (or, at least, was being used), and how he came to know it was now obsolete?

On another level he was concerned for his students, those who were preparing to come into the professorate. Would they be able to succeed in this new world? Was our institution providing them the kind of knowledge, the training and the skills, that the university of the next century (I should say that this conversation was conducted **last** century) would demand? What **would** the university of the 21st century look like, and how could we do a better job of preparing future faculty to work, and succeed, in that environment?

Before I could answer any of these questions, or give my own futurist vision of things to come, I though it best to look backwards for a moment and see how new technologies have impacted education over the years past. Perhaps this might lend some insight into how the institution, and society, would cope with our rapid technological advancements. And, if nothing else (as my doctoral advisor always told me), chanting the ancients is always a great way to start any speech.

Over 1,000 Years Ago

I begin, therefore, with a look back at a time before the modern, western university, over 1,000 years ago near the end of the first millennium. At this time education existed in primarily four arenas: at home, at church, at court, or with a master.

Home education, through the early years (about age seven for the gentry, and almost exclusively for the peasant) consisted of those things one needed to know to exist: daily living, hunting, growing grains and other foods, and interacting with one's peers. Reading was a limited skill, restricted only to a very small segment of society. Instead, the emphasis was on memory and knowledge of local conditions (travel being that which one could accomplish on foot in a single day).

Theology, carried to the masses by the priestly class, delivered rote instruction designed to ensure obedience to God and King. Monastic and cathedral schools focused on the preservation of knowledge and its fit with doctrine, its aim to produce a literate priestly class. The seven liberal arts, codified into the **trivium** (grammar, rhetoric, and dialectic (logic))—the "arts" part of the curriculum—and the **quadrivium** (arithmetic, geometry, astronomy, and music)—the "science" part of the curriculum—by Martianus Capella during the fifth century, served as the cornerstone for this religious education. Boys as young as ten could be accepted to such a school, where they might study to the age of 18 before being admitted as a member of that order.

The sons of the gentry and nobility would spend their first seven years or so at home, the next seven as a page, and the next seven as a squire. At home he would be educated in morals and religion; as a page in manners, reading, writing, and other social skills; as a squire to a master in the arts of hunting, fighting, and waiting on his master or lord. Upon reaching 21 years of age the son would undergo an elaborate religious ritual, receive a blessing on his sword and armor, and receive his knighthood.

The fourth arena was that of apprenticeship, reserved for those engaged in a trade or craft. Apprenticeships were a contract most often formalized between a male child (and his parent or guardian) and a master in that trade or craft. In exchange for certain number of years of, essentially, indentured servitude (oftentimes in addition to other items of value, similar to a dowry), the master would agree to teach the apprentice their skills. These tradesmen, in the later part of that first millennium, organized into gilds for the purposes of protecting their earnings through the domination of trade in certain finished goods by the restriction of those who could be taught, and practice in, that trade. These gilds were to exert enormous influence over medieval Europe, and serve as the forerunners of both unions and universities. To illustrate, the following is a fictitious account of a commencement address that might have been given, circa 950 A.D. from a master to his graduating apprentice (it has been written in relatively modern English for your convenience):

> William, son of Frederick, the day has arrived when you must leave this shop and strike out on your own. You came to me as a mere boy of nine years when your father contracted your services to me apprentice. Side by side with my own sons over the last seven years you have learned the trades-craft of leather smithing, as taught to me by my own father and to him by his. As your master I have done my best to teach your these skills and learnings such that you might prosper. I know I have been, at times, a hard master, pushing you to work beyond the light of day. Throughout, despite all, you have not taken your leave of me nor complained to the gild. You have learned, and in doing so have developed a skill worthy the status of journeyman. Your master piece work, examined by the highest within the gild authority, demonstrates your quality and craftsmanship. Be mindful of the imitation, the cheap imposter who would weaken our gild strength with inferior product or underpriced goods. Likewise listen not to those who would replace the work of men with that of machines. Go forth, now, and find such work as you are able. Likewise too find a bride, have many sons, and teach them the skills I have so taught you. Be good and true to your trade, your gild and your God, and may you live beyond my own years of thirty and two.

By the 1200s the formalization of gilds was nearly complete. Gilds helped to insure uniformity of produced goods, provided protection against the abuse of apprentices, and normalized the route through which an apprentice might proceed—in education and experience—to become a master. These gild policies were later oftentimes codified into law, with by the 1600's much of trade law resting on the prior policies and practices of the various gilds.

It must be remembered, though, that the primary purpose of the gild was the protection of its members from deleterious influence. Such influences could come from inside its own ranks (such as the advancement of an apprentice inappropriately skilled), or from the outside (individuals or foreigners seeking to cut in on the tradesman's livelihood). New technologies, when they did appear, would pose a similar threat to the income of gild members and would be treated in the same way. Only when the members of the gild had time to adapt to the new technologies, either through retooling or re-education (or both), would the new technologies be accepted.

The Origins of the Modern University

Our modern institutions of higher education trace their roots back to events of the late 1000s and early 1100s. At this time the first university (or **studium**) was established around 1088 in Bologna, Italy. The University of Paris was founded just a few years later in 1119, the different colleges of Oxford University between 1167 and 1185, and Cambridge in 1209.

These early universities were not created by kings or popes, nor by the wealthy or landed. Instead, they were formed as common protection societies for students and teachers. Indeed, the very word university comes from the Latin word **universitas** meaning a "corporation" or "gild", a union of scholars. Unlike today, students were very much in charge of these early institutions; according to Gwynne-Thomas:

> The students specified the length and pace of the lectures (since note taking was imperative in the absence of readily-available texts), and could dispense with unpopular instructors who failed to attract more than five students to their classes.

In addition, students determined the times and places of lectures, set rules concerning the nature and conduct of faculty (including salaries), and would strike (or leave town entirely) if local conditions were not to their liking. Town merchants, profiting off of the collection of students and teachers in their towns, quickly learned to acquiesce to lower rents, food costs, and the university's control over students' public behavior lest the institution up and leave the town (taking all its revenue with it)!

Students organized themselves into **nations—**really dormitories for students coming from similar backgrounds and geographic regions—which in turn organized together to form the higher structure of the institution. Faculty, in turn, formed their own gilds, called **collegia** (colleges), to promote the faculty interests both with the students and in the town in general. Eventually these nations and colleges somewhat merged and came to dominate university life as we know them today. Universities other than Bologna followed somewhat different models, with the University of Paris initially organized around masters of the institution (the professors).

Students entering one of these early universities would normally do so at about the age of 14 to 16 years, enrolling for study under a particular master. Although not all from the upper classes, most students could read and write Latin, had studied from Capella's seven liberal arts, and were quite capable of living on their own. Depending on the field of study, the student would engage for between four and seven years, refining his skills at reading, writing and speaking. A **baccalaureate** (from the Latin **baccalaureus**, according to one source being roughly equivalent to the word "cowboy", or one who is just beginning his candidacy for a degree) would recognize these abilities, and the student's intention for beginning serious study. Only later on did this designation become a degree in itself, intended for those who did not intend to pursue teaching as a career.

The student would then engage in specific study, again under the tutelage of a specific professor (or group professors), in a particular field. After additional years of study (three to four for a Master of Arts, perhaps as long as 16 years for a Doctorate, with considerable variability from field to field and university to university), the student would be required to engage in a dispute (a defense of his thesis, consisting of both a private and a public discourse). Like the apprentice craftsman, the apprentice professor would present his "master piece" to the authority of his gild (the "nation" of his "university"), seeking recognition and the awarding of the degree and, with it, the **licentia docendi** (a licence to teach anywhere). Such a license would actually be granted typically by the vice-chancellor, using language such as this from the University of Paris from the mid-1300s:

> I, by the authority invested in me by the apostles Peter and Paul, give you the license for lecturing, reading, disputing, and determining and for exercising other scholastic and magisterial acts both in the faculty of arts at Paris and elsewhere, in the name of the Father and of the Son and of the Holy Ghost, Amen.

If you think this is much different than what we do today, consider the rules related to the **inception** (the process for actually receiving the degree) from the University of Bologna in the mid-1200s:

> Wherefore, there is required a vigorous examination by some lecture or disputation in which he must answer arguments. And then he has to be approved or rejected by a ballot of the members of the college according as the majority vote. And by the chancellor or vice-chancellor of the university is given him license to receive the doctorate, either in theology or law or philosophy or medicine, and the power of occupying a chair, or lecturing in universities, disputing publicly, interpreting, glossing, and the like. Then the recipient of the degree, after making a brief speech in praise of the faculty, requests one of his promoters whom he names and who is present that the insignia of the doctorate may be given him. And that one rising, after commending the candidate's proficiency in the subject in which he is to receive the degree and commending the doctorate, gives him the insignia: namely, first a closed book that he may have that science close and familiar in mind and may keep it sealed from the unworthy and in such respects as it is not expedient to reveal. Second, he gives him an open book that he may teach others and make things plain. Third, him gives him a ring of espousal to that of science. Fourth, a cap as a token or aureole or reward. Fifth, the kiss of peace.

At this time the terms Master, Doctor, and Professor were essentially synonymous, with only minor differences existing between fields of study and particular schools. The real prize of the whole effort was the combination of the license to teach and acceptance into the gild of the professors. Thus the early university and, indeed, its modern counterpart, are seen to differ little from the trades craft gild structures of the late first millennium—structures design primarily to restrict entry into a particular profession (and, by doing so, to protect the earnings power of those in the profession) and, secondarily and much later, to insure the quality of the craft so produced.

Thus, the structure of our modern university was essentially established and routinized by the late 1200s. It has remained in this form for, I believe, two main reasons. First, it seems to work, or at least serves a function adequate enough for society that, over time, there has been no major reason, no uprising, resulting in a change. Second, the university structure has not faced any real challenge—technological or otherwise—for which it could not adapt. That is, I think, up until just recently. To understand this second point better let us take a look at some of the technologies that have, over the years, had some impact on higher education.

Books: The First Technology

Clearly the first technology that had a major impact on the university was the printing press. To have realistic mass production of books one must combine four major technologies: paper, movable type, ink, and means for putting the first three together. The mass production of paper—originally from old clothing (boiled into a pulp, spread over a screen, then dried, hence the terms "linen" or "rag") originated in the first century A.D. with the Chinese. By the ninth century these Chinese printers had mastered techniques for setting characters into wooden blocks to mass produce books. The real breakthrough occurred, of course, in 1450 when Johannes Gutenberg was able to combine sturdy metal characters into a form with a relatively easy process for inking that was the forerunner of the modern printing press.

Gutenberg's steel punches consisting of 264 movable and reusable characters; his combination of heated oil, resin, and soap as an ink slurry; and his transformation of a wine press into a printing press was truly innovative. And while his Gutenberg Bible was the most publicized of his works, he actually made most of his money through the printing of indulgences—a kind of "do not stop on go, do not collect $200" pass out of purgatory for those wealthy enough to buy them from the Church. Like many small businessmen, though, Gutenberg's ideas were better than his execution, and while the notion of a printing press was first rate Gutenberg never profited all that much from his invention.

Despite the potential of the printing press, it was not until almost 300 years later, in the 1730s, that really cheap printing emerged. Later inventions of the steam engine, paper being fed into the press from large rolls, and the use of a cylindrical printing plate to speed production times transformed the process. By the early 1800s, books, magazines, and newspapers were now somewhat affordable. Prior to that, printed books remained relatively rare, expensive items for which few had access.

Its Impact on Education

The professors and students of the late middle ages and renaissance certainly used printed books, in addition to hand-copied texts, when available and affordable. Students would often band together to share in the purchase, or more commonly the rental, of texts too scarce and costly for any one individual to own (perhaps a precursor to our modern bookstore book buyback and used textbook trade). Early professors would be said to "read their lectures", quite literally reading the textbook, to their students. The professors' explanation of the text, more important the more complicated or vague the text was, would often be written in the sides or margins of the text next to the original narrative. This method of enhancing and expanding upon the meaning of the text, known as glossing (the glossing mentioned in the prior inception narrative) was often formalized in the recopying or reprinting of the text. With some particularly difficult subjects, especially law, a single gloss was often not enough, and it was not unusual to see texts with two or three levels of gloss! The term "glossing over" a text, then, carried a much different meaning years ago than it does today, although we still have the remnants of glossing in modern footnotes and endnotes.

The real impact of the book, though, was not so much the mass proliferation of knowledge as it was the standardization of knowledge. Initially one had to rely solely upon a single master, whose own skill and capabilities were all you had from which to learn your craft. Books allowed students to have multiple masters. The dialectic was not between people, as it had been in Aristotle's time, but rather among their writings. Professors became increasingly known for their ability to sort, organize, and recite from these writings—the "chanting of the ancients." Possessing a large library not only spoke to one's wealth, but also to ones dedication to learning, since presumably one had read (and could recite from) those printed bodies of knowledge.

Machines: The Second Technology

The second class of technology that seems to have had an impact on the university were mass produced machines, especially those designed to aid a single person in doing repetitive tasks. These machines generally fall into two categories: those designed for computation, and those designed for transcription.

Machines for Computation

The first of the computation machines is generally credited to Blaise Pascal, although there is some suggestion that both Leonardo da Vinci and Wilhelm Schickard had prior, perhaps successful, attempts at creating such devices. Pascal, in 1642 at the age of 18, created a calculating machine (called the Pascaline), capable of performing eight digit addition and subtraction. His mechanical device, only reproduced in small numbers, improved upon the earlier abacus by simplifying the operator skill required for its effective use.

Like the printed book, however, mass produced calculators would not enter the market until almost 200 years later, when Xavier Thomas de Colmar created the Arithmometer in 1820. So successful was this particular machine (it could add, subtract, multiply, and divide) that it was still manufactured over 100 years later, through the 1920s. A variety of mechanical devices followed, including the slide rule which was just an extension of John Napier's "numbering rods" (sometimes call "Napier's Bones" due to the resemblance to human bone, having been made out of ivory), invented in 1617 to simplify multiplication through the use of logarithms. Electronic calculators, at first motor assisted mechanical machines, then later devices based solely on circuitry, made their appearance in the 1950s and 60s.

Machines for Transcription

The Sholes and Glidden Type Writer, first produced in 1874 by the E. Remington and Sons company of Ilion, New York, represented the first mass produced machine for doing, on an individual level, what the printing press was doing on the large scale. Inspired by an idea in the journal Scientific American (which actually coined the term "typewriter"), this original machine more resembled a sewing machine—sitting on a platform connected to a foot treadle to operate the carriage return—than it did a modern day typewriter!

As with many of the early machines is was a clunky thing, typing only in capital letters and frequently jamming or breaking outright. Later machines improved on these features, including providing a way for the typist to actually see what he or she was typing while they were typing it (the early machines having the paper below the operators sight line). These early machines also experimented with a variety of keyboard layouts, eventually settling on QWERTY as the standard we use today.

As an aside, QWERTY was not chosen to slow down typists to prevent jams (as was explained by Stephen Jay Gould in the book "The Panda's Thumb"); rather, Sholes wanted to increase typing speed! Manufacturing capabilities at the time placed practical limits on what could be produced with sufficient precision. Early typewriter keyboards, arranged alphabetically, jammed too easily. By using a study of letter-pair frequencies prepared by educator Amos Densmore, Sholes was able to separate commonly paired letters to opposite sides of the mechanism, reducing the likelihood of clashes and actually increasing the speed of early typists. In 1932 Professor August Dvorak of Washington State University, on a grant from the Carnegie Foundation, created a new keyboard layout that placed more of most commonly used keys on the home row. While the efficiency of such an arrangement is still under debate, the prominence of QWERTY makes mass change unlikely.

Putting the Two Together

Putting these two together—the calculating machine with the transcripting machine—and you have today's modern computer. Of course, the modern computer didn't actually start out that way. It, too, went through a series of developmental steps.

Perhaps the earliest concept model of what would become our modern-day computer was proposed, although never successfully created (due to the limitations of the manufacturing tolerances of the time) by Charles Babbage. In 1822 he proposed a device called the **Difference Engine** which would, he hoped, do away with the inefficiencies and inaccuracies of large scale calculations. After 10 years of work, Babbage revised his original design into a new **Analytical Engine**. This new machine, proposed by Babbage in concert with August Ada King, the Countess of Lovelace would have been, had it been successfully built during his time, easily recognized as the mechanical version of any modern computer. Its innovation, thanks to Lady Lovelace, would have been the ability to be programmed with an infinite varying set of instructions; to be able to carry out those instructions (including conditional, or "if ... then ...", series); and to report the results of such a programmed run. This earliest computer, when finally constructed in more modern times, was as big as a locomotive and powered by steam, yet possessed all of the constructs of a computer: an input device (punched cards, read in the same way as those used in Joseph-Marie Jacquard's looms); a "store", or memory, for holding up to 1,000 values of up to 50 digits each; a "mill", or central processor, that controlled the execution of the instructions on the punched cards; and output devices to print the results of a run!

Herman Hollerith, in 1889, borrowed this idea of using punched cards to improve the speed of the U.S. census tabulation from over 10 years to about 6 weeks! Although not a true computing machine, the idea of punched cards as a means of computer input remained through the 1980s. Later developments by John V. Atanasoff, a professor from Iowa State College (now Iowa State University, and his graduate student Clifford Berry, extended the work of George Boole and his clarified system of binary algebra to electronic circuits. In 1940 their work culminated in a prototype machine that, unfortunately, never went much beyond that stage.

World War II saw other developments in electronic calculation from both German and British scientists, although it was a Harvard engineer named Howard H. Aiken who, in 1944, finally created a working, large scale all-electronic calculator know as the Harvard-IBM Automatic Sequence Controlled Calculator, or just Mark I. Shortly after that the Electronic Numerical Integrator and Computer, or ENIAC, made its appearance courtesy of the University of Pennsylvania and inventors John Presper Eckert and John W. Mauchly. ENIAC, using electronic tubes rather than relays like the Mark I, was a true general purpose computer. Although much less powerful than the handheld calculators of today, ENIAC had the advantage of using of 18,000 vacuum tubes and consuming over 160 kilowatts of power when running!

The invention of the transistor (in 1948), then of the integrated circuit (in 1958), then of Large Scale Integrated Circuits (or LSIs), Very Large Scale Integrated Circuits (VLSIs) and, by the early 1970s, Ultra Large Scale Integrated Circuits (ULSIs), dramatically reduced the size needed for computing hardware while simultaneously increasing its speed and power. The Intel 4004 chip, created in 1971, followed by the 8080 chip, spurred the development of early computers from Commodore, Radio Shack, and Apple. IBM introduced its first personal computer (or PC) in 1981, with the Apple Macintosh making its debut in 1984. Development has continued since then, with new generations of computers seeming to appear about every 18 months. New development is approaching a crossroads, however, as the ability to miniaturize components on an integrated circuit fast approaches theoretical maximums (where circuits are actually small enough that quantum electronic effects, seen in individual atoms and electrons, interfere with computing)!

Its Impact on Education

The impact of these, and similar, machines on the university was both interesting and unexpected, and has really been seen more in the last two decades than at any time before. Prior to their introduction students needed to be able to master the mechanical skills, the operational skills, related to writing and arithmetic. Sharpening a quill, performing arithmetic "long hand", penmanship—all were considered traits that a serious scholar needed. The increasing use of these machines radically changed, for the first time in over 800 years, the kinds of skills a student ought to have mastered. More importantly, these changed portended a more serious change yet to come; namely, the need for students to acquire significant skills and knowledge that their teachers, the masters, may not themselves have!

The real impact of computers on higher education, however, seems to be the mass storage, indexing, searching, and retrieval of information from stores previously unthought of. Whereas scholar of the prior century could, at best, hold the knowledge of a few hundred volumes in his or her head, the scholar of today has ready access to thousands—perhaps even millions—of works. High capacity disk drives, CDs and DVDs, and disk arrays compress not only the works themselves, but the indexed characteristics of the works. Our current desktop machines not only calculate faster, they also search faster, introducing for the first time in history the notion of "data mining" as a real term. Memory, even the possession of books, is now less important than the ability to manipulate these machines to locate information applicable to a particular issue.

Communications: The Third Technology

Telegraphy

On the 24th of May, 1844, Samuel F. B. Morse received the first long distance transmission of a coded message over wire. Morse's assistant, Alfred Vail, located in Baltimore, Maryland sent the text "What hath God wrought?" to Morse, who was in the Supreme Court room in the Capitol. This message, recorded on paper tape (sounded telegraphy, with audible clicks and clacks, did not appear until 1849) really signaled the beginning of the communications age. Just a few years later, telegraph lines began spanning the country, and companies like Western Union arose as leaders in the new long-distance communications industry.

By 1888 the volume of information being sent by telegraph had increased to the point where telegraph operators were beginning to report a new malady known as "Telegrapher's Paralysis". Pain, numbness in the fingers, and a stiffness and difficulty moving the hand and wrist were common. Such symptoms are today known as "carpal tunnel syndrome". Changing from a vertical telegraph key to one mounted horizontally let telegraphers place their hands and wrists in a more natural position.

Telephony

> When a permanent magnet is moved towards the pole of an electromagnet, a current of electricity appeared in the coil of the electromagnet; and that when the permanent magnet was moved from the electromagnet, a current of opposite kind was induced in the coils. I have no doubt, therefore, that a permanent magnet, like the reed of one of my receiving instruments, vibrating with the frequency of a musical sound in front of the pole of an electromagnet, should induce in the coils of the latter alternately positive and negative impulses corresponding in frequency to the vibration of the reed, and that these reversed impulses would come at equal distances apart.

These words, written by Alexander Graham Bell in 1874, describe his breakthrough idea that would combine the message carrying capability of the telegraph with his own developments in the electronic reproduction of sound. A serendipitous occurrence on June 2nd, 1875, provided the final insight. In this instance Bell, and his assistant Watson, had set up several telegraph stations using a tuned reed to produce a particular tone when the telegraph key was depressed. A corresponding tone on a tuned reed relay at the other end of the telegraph wire in another room was to reproduce the sound carried electronically over the wires. Wrote Watson of the experiment:

> The undulatory had passed through the connecting wire to the distant receiver which, fortunately, was a mechanism that could transform the current back into an extremely faint echo of the sound of the vibrating spring that had generated it, but what was still more fortunate, the right man had that mechanism at his ear during that fleeting moment, and instantly recognized the transcendent importance of that faint sound thus electrically transmitted. The shout I heard and his excited rush into my room were the result of that recognition. The speaking telephone was born at that moment.

It took two more years of development and testing, which by January 20, 1876 culminated in a patent application of the first practical telephone. Continuing developments on this theme included: operated staffed switching centers; direct pulsed dialing; automated switching centers; dual-tone multiple frequency (DTMF) dialing; multiple-line business and residential service; overseas land-line and satellite calling; and wireless connections and cellular phones, all culminating in our ability to pay $1.10 to make a local call from our hotel rooms!

The Internet

Packet switched networks, enumerated by Paul Baran of the RAND Corporation in a 1962 report to the U.S. Air Force, detailed one way for the government to create a telephone network of computers that could survive a nuclear attack. Wrote Baran:

> Packet switching is the breaking down of data into datagrams or packets that are labeled to indicate the origin and the destination of the information and the forwarding of these packets from one computer to another computer until the information arrives at its final destination computer. This was crucial to the realization of a computer network. If packets are lost at any given point, the message can be resent by the originator.

The Advanced Research Projects Agency (ARPA), later renamed the Defense Advanced Research Projects Agency (DARPA), took on the task to develop such a network. In 1968 ARPANET came on line connecting four host computers over 50 kbps lines (just slightly faster than the typical home telephone modem of today). The Transmission Control Protocol/Internet Protocol (TCP/IP) can into existence in 1973, with ARPANET having grown to over 23 interconnected machines. The next year Vint Cerf and Robert Kahn first used the word "Internet" on a paper about TCP/IP. USENET and BITNET were introduced in 1979, using a store-and-forward strategy to connect computers for e-mail and Listserv. By 1984 T1 lines, carrying data at 1.5 Mbps (25 times faster that the 56 kpbs original lines) began to appear as the National Science Foundation Network

(NSFNET) began to replace the civilian side of ARPANET. T3 lines, capable carrying data at 45 Mpbs, were conceived in 1988 and in wide use by 1992 as the primary backbone of the national network.

The notion of the World Wide Web was also conceived in 1992, although it was not until one year later that Marc Andreessen at the University of Illinois spearheaded the development of a graphical user interface for the web known as "Mosaic". By this time the number of hosts on the network had grown to over 2,000,000 computers. Asynchronous Transfer Mode (ATM) replaced T3 lines in 1994, increasing the speed of the network's backbone to 145 Mbps. By 1995 over six and one-half million hosts were on the Internet, and in 1996 network speed increased to over 622 Mpbs.

New technologies are pushing the speed limits over 2.5 Gpbs, with home users finally being able to benefit from these innovations as "broadband" technologies, with speeds of between 275 kbps to 10 Mpbs, connect home users to the backbone. The latest estimates for computers on the Internet is at well over 100 million machines with over 22 million web sites available for browsing. Popular among these web sites is one called "The Gutenberg Project" (http://www.gutenberg.net) which makes out-of-copyright texts available for download free of charge. Of course, numerous pay-for-product sites also exist providing text, search and index, audio, video, and very entertaining multimedia on demand.

Its Impact on Education

Computers and the Internet are placing enormous pressures on institutions of higher education in a number of different ways. The first of these is in distance education.

The beginnings of distance education in the United States is generally identified with correspondence courses in shorthand first advertised in the *Boston Globe* in 1728. Large scale distance education, however, had to wait until the creation of the Open University in the United Kingdom in the 1970s. Since then technology has increased the diversity in which distance education courses may be conceptualized, created, and delivered. Today students engage in asynchronous web-based tutorials, e-mail discussion lists and group forums, and live chat rooms (typewritten, audio, and video) from sites all over the world. Traditional geographic boundaries no longer apply, and many institutions are looking towards Internet-based computer-assisted distance education as the means to expand their student bodies (and, therefore, bottom lines).

Another pressure is related to traditional, campus based instruction. Students have become more technically savvy, more computer and network literate, than many of their instructors. Our fast paced, entertainment oriented culture colors how they see their world, including higher education. Today's students expect their classes to be as technically rich, as rapid and entertaining, as what they see on television and experience through mass marketing. When it isn't, administrators begin to worry that they will use the power of the Internet to make other choices, physically or virtually attending other schools more to their liking.

Unfortunately, with just a few exceptions, many of these institutions of higher education have been glacially slow to adopt and acquire new technologies. Costs are huge, and more often than not institutions undertake these acquisitions at the expense of human capital and infrastructure maintenance. One also wonders whether the typical faculty member, even if they have the willingness to retool for the new technologies, has the time! This poses a serious problem, in which the Masters of the new information age seem to be the Students themselves!

Where Are We Going?

What does this all mean? Well, first let me summarize:

(1) Western institutions of higher education, first conceived of in the early part of the second millennium, have survived to today essentially unchanged in form.

(2) Recent technologies, however, are poised to change several key foundational aspects of these institutions. Specifically:

(a) For the first time Professors are increasingly **not** the Masters of the information technology of their trades craft;

(b) The sheer volume of information now readily available insures that hyper-specialization is a necessity, in addition to requiring increasing technological competencies just to access that information;

(c) The rate of technological change, once measured in centuries, is now measured in months, making the task of just keeping current in **only** the technology (let alone the content area) a near full-time proposition;

(d) Students (or apprentices) have increasingly easy and inexpensive access to means of education and certification that skirt, or entirely bypass, the traditional institutions, and are becoming more willing to exercise those alternatives with their buying dollar; and

(e) State support for higher education is not increasing at a pace that would support the current infrastructure as well as new technology.

New Technologies on the Near Horizon

There is one other concern not yet mentioned. The technologies that we all see in front of us today are **not** the technologies that we will be working with in the coming years. Unlike our predecessors for whom change came at a relatively modest pace, our information technology world thrives on change, on new ideas. We can, however, look down the road to the very near future with some certainty. Changes we should expect to see within the next five year include:

(1) *High speed wireless local networks on campus, in the workplace, and in our homes*. Already on the market are wireless network cards, costly only slightly more than their wired counterparts, with speeds of up to 11 Mbps (traditional wired Ethernet is only a 10 Mbps connection). The mobility these devices allow, and the freedom from costly wiring, make them worth the additional costs.

(2) *Broadband connections into our homes*. If you live in most metropolitan areas you probably already have access to either high speed cable modems (over the same cable that bring TV to your house) or fast Asynchronous Digital Subscriber Line (ADSL) technologies (using your telephone wires). Rural areas are served by fast satellite download services over your satellite TV provider. Telephone and entertainment companies are now competing to establish the next standard in which telephone, television, and high speed network access are all brought into your home over a single connection.

(3) *New ways of interacting with your computer*. As any slow typist can tell you, using a computer can be a real pain. New technologies including improved voice recognition, handwriting recognition, and virtual keyboards (computers that detect your intent by the simple movements of your hands and fingers without contact with any real keyboard or mouse) are already in use. Computer displays are becoming lighter, thinner, and more flexible, with one prototype unfolded from your pocket when needed and another embedded as a part of your eye glasses.

(4) *Personal digital assistants (PDAs) that replace, in power and functionality, most desktop computer needs*. Current PDAs carry slimmed down versions of popular desktop applications, with some having memory capacities and processing speed equal to that of desktop computers from just a few years ago. Battery powered, with high resolution color displays, these devices will merge with your cell phone and pager to provide a single unit for all your portable information, communication, and web browsing needs.

(5) *Books, and other audio and visual entertainment titles, that only exist in electronic form*. Napster showed the world just how easy it is to “rip” (translation: copy from an audio CD to a computer disk) songs and share them with others over the Internet. Stephen King’s latest book has been distributed entirely online, by-passing the traditional paper format and big publishing house with King still raking in huge direct payments. Electronic books, thin and lightweight battery powered tablets capable of storing and displaying numerous titles complete with graphics, hypertext links, audio and video content, now exist from several manufacturers, and publishers are competing to determine which format will work best.

(6) *Internet search engines that learn from your choices and style, remembering, adapting to your preferences and foibles*. Such engines become tailored to you, the more you use them the better they become.

(7) *A continued reduction in the use of paper for everyday transactions*. On-line forms, e-submissions (college applications, tax filings, reports), and record retrieval (bank statements and bill paying) are just some of the current applications. Signed into law this year was new legislation permitting the use of e-signatures in certain commercial and legal transactions. More and more companies and universities are putting important references and documents on line, finding it cheaper and faster than printing them on paper.

(8) *New forms of computing that promise even faster speeds and smaller sizes*. While current computing technology is very near the limit of what can be performed without quantum mechanic interference, three new developments hold potential for the future. The first of these new methods involves the use of massively parallel machines, where hundreds or thousands of relatively low-cost processors are ganged together to work on a common problem. SETI, the Search for Extraterrestrial Intelligence, recently employed a distributed version of such a technique in enlisting hundreds of thousands of Internet users to donate their spare compute cycles (that time when the computer is on but you are not really doing anything) to analyze radio signals from deep space. The second of these methods is called quantum computing. Quantum computers would, according to the theories being tested, operate near instantly and with orders of magnitude of simultaneous processing power over traditional binary machines. These quantum machines would make solvable problems completely intractable by current standards, and would threaten even the most secret of encryption schemes. The third method is known as bio-electronic computing, the merging of biological and electronic systems for computational power. Bio-electronic computers give rise to visions of intelligent robots or humans with augmented brains—currently still in the realm of science fiction, but for how long?

These are just some of the technologies on the near horizon. What will come beyond these in ten, twenty, or fifty years? And how will our institutions of higher education adapt to, or even prepare for and anticipate, these changes?

Predictions for Education from 1985

Before I make any predictions I thought it best, just one more time, to look back a bit and see if there was some wisdom to be gained from those who had come before. In this case, though, I chose a more recent source. In 1985 Martin Cetron published a text titled “Schools of the Future”, a work developed in conjunction with the American Association of School Administrators, and designed to predict what public schooling might look like in the year 2000. I think, as it is the year 2000, it might be illustrative to look at these predictions for their future, our present. I offer several of their predictions from 15 years ago as is, without comment.

(1) High tech will cause workers to re-train approximately every five years just to stay current in their jobs.

(2) Public schools will do the bulk of this re-training, perhaps three to four times in a person’s career.

(3) The average work week will decline to approximately 32 hours in 1990, then to 20 to 25 hours in 2000.

(4) More businesses will be involved in apprenticeship training.

(5) Annual teachers’ salaries will be raised to within ten percent of parity with other professionals requiring college degrees.

(6) Performance-based merit pay will be in effect in most school districts.

(7) Paid sabbaticals will be offered to professional educators in many school districts; often the districts themselves will pay for teacher re-training—this will probably occur three to four times during teachers’ professional careers.

(8) Teachers’ unions may be less contentious in the nineties or in the 21st Century. As teaching and pay conditions improve, union membership may decline.

(9) The school day will increase from an average of about six hours to between seven and eight hours, and the number of days in session each year will increase from about 180 to between 210 and 240.

(10) All students will have IEPs.

(11) Computers will replace textbooks.

(12) Vocational education will expand, with schools and employers working more closely together.

(13) One-tenth of primary school students and one-quarter of secondary students may use interactive television to study at home one or two days per week.

And in specific regard to technology . . .

(14) By 2000, computers will be available to 25% of the poorest school districts on a ratio of 1 per 8 students. In contrast, 25% of the most affluent school districts will have a ratio of 1 computer to 4 students.

(15) Many of the details that plague administrators in 1985 will be taken over by computers. These will include: 1) scheduling, 2) attendance records, 3) payroll, 4) personnel data (certification), 5) bus scheduling, 6) cafeteria management, 7) inventory management, 8) student records, 9) budgets, 10) repair and maintenance scheduling, and 11) scheduling of extracurricular activities. As a result, administrators will have more time to concentrate on instruction and academic achievement for all students.

My Crystal Ball

So what do I think will happen, where the world will go and how higher education will fare? Following are my predictions, perhaps no better (or worse) than those from Cetron in 1985.

(1) Public K–12 education, will remain virtually unchanged for the foreseeable future. Increasing numbers of single-parent households, and dual-parent dual-career couples, need someplace safe, nurturing, and cheap to send their kids each day.

(2) Technology will make increasing numbers of options available to K–12 teachers and students resulting, I believe, in a continued erosion in schools’ ability to offer any but the most basic of subjects. Foreign languages, advanced math and science, music and art, and other so-called electives will be made more affordable over the Internet and on CD instead of live and in-person.

(3) Teachers will increasingly be at a disadvantage when it comes to knowing about, operating, and using advanced technologies. Their role as content area expert is long gone, and the current role of facilitator will likewise vanish. I am not sure what their next role will be.

(4) As was true in the 1200s, most parents want their children to ease their way into full adulthood . “Camp undergraduate” provides just that opportunity, although increasing numbers of undergraduates will be older, working adults returning to school for the first time in the evenings, on weekends, and from a distance.

(5) More students will opt to enter the work world directly, and will be educated on the job by their employers.

(6) Enrollment in graduate and professional programs will continue to increase. With that will come more demand for off-campus, flexible schedule, and online education. Higher education will respond by making more demands of faculty, changing traditional work roles and expectations in order to remain competitive.

(7) Many companies (the most recent example being the United States military) will examine and adopt Just In Time (JIT) education philosophies. Training will occur when you need it, for what you need it. Education will be continuous and on-going, but highly job oriented.

(8) Public university will be even more entrepreneurial, less publically supported, and more in competition with privates schools and corporations. The produc-

tion of knowledge for knowledge's sake will decrease, as our accountability oriented culture demands an immediate return for its investment.

In Conclusion

To finish this story, I go back to the original questions my colleague asked me. Could he still be an effective professor if he could not operate well the technologies of today? Are we doing a good enough job to enable our students to succeed in the world of tomorrow? Are we undergoing the shift of paradigms referred to by Kuhn?

Yes, I told him, but not in the way he thought. It is not the computers, or the Internet, or all these other technologies that is causing this paradigm shift, this radical change in terms of how we look at the world. Rather, it is what these new technologies enable us to do! Information, and the knowledge that comes from the study of, and reflection about, information, is becoming easily and relatively inexpensively available to everyone, at almost any time, in almost any place. The university of the next century will not need gild Masters to apprentice students already more skilled in the technologies than they are. The content area expert, the "sage on the stage", will be an anachronism. The universities will instead need instructional developers—people who can sift, sort, organize, and create presentations and interactions of information that others will use. The universities will need instructional troubleshooters—facilitators who can help direct lost and confused students to new sources of information, different styles of information presentation, and creative ways to resolve problems. The universities will need instructional humanists—people who interact with other people to continuously remind each of us why we ask the questions, to consider the ramifications of our actions before acting, and to work to improve our lot as well as that of everyone else.

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