POWER AND PEDAGOGY:

Transforming Education through Information Technology

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To Moira,
for the example of her growth and maturation,
and to Max,
who has read, encouraged, clarified, and cajoled,
and best of all, who has inspired through her precept and example,
the effort to pack compelling force into a trim form.

Contents

Preface

Educators propound reforms, but schools remain the same. Without material agency, new methods fail. A scheme captures the educational imagination -- spokespeople think it out, the daring to try it, researchers document its effects, and the committed demand its adoption. Thus, the idea diffuses from various centers -- but then, sporadically, resistance builds, enthusiasm falters, influence weakens; ineluctably, distinctive practices gravitate back to the norm. Pedagogical weathering soon makes the new shingles indistinguishable from the old.

Without political vision, technological innovation leaves the quality of life unimproved. Anticipations of future technologies depict wondrous tools for living, but then culminate with "a day in the life," usually a banal office routine with little at stake that was different from what would be at stake in the corporate office anywhere today. Such visions do not inspire people to solve human problems old and new, to join together with shared hopes and historic aspirations, enabled now to act on issues hitherto in- accessible to the common weal.

We need to join pedagogy and power. Educators inspired by visions of human potentiality need instruments of action, substantial agents of change, with which to work. Technologists creating new means for bringing intelligence to bear upon the work of the world need a civic agenda, a vision of historic possibility, consciously espoused and responsibly defended. Without power, educators will continue cloaking their delivery of lame services in high-minded impotence. Without pedagogy, technologists, bleating complacent corporate compromise, will recreate the injus- tices of the contemporary world with the new-forged tools that might otherwise transcend it. Educators need power, not purity; technologists need vision, not predictability. Together educators and technologists have the historic opportunity to improve the civic prospect -- that is the message of Power and Pedagogy.

Chapter One - A Perspective on the Task

Let's look ahead. In the twenty-second century, how might an historian of education sum up the major changes in pedagogical practice over the sweep of time? Imagine that we commission Elizabeth Ironstone, leading authority on the computer as an agent of change, to study these changes. She reports, not in the multimedia of her time, but in the prose of ours. This might be her executive summary, introducing Toward the Educative Polity.

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Through most of history, education was a loose system of ap- prenticeship and indentured service in households, the main loca- tion of productive activity. Those who wanted their children to be- come learned employed tutors to help them out. A few schools ex- isted within specialized institutions, such as cathedral priories and monasteries, but these were not like the schools that eventually proliferated, for students were not divided into classes or grouped according to age.

Around 1500, a major pedagogical transition began as printing with moveable type made an unprecedented era of educational development possible. But the transition was not a quick and simple change: to bring it off, innovators had to develop a complex of different, yet interrelated, educational strategies, which together eventually made mass schooling for all a practical reality. Key steps in this process involved:

> » Developing a characteristic place, a set of classrooms where children could be grouped by age, with the classes organized together into a school; and creating a standard unit of time, the fixed instructional period, which would allow for planned scheduling of the academic day and year and for organizing subject-matter into a sequence of measured lessons;
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> » Discovering how to manipulate motivational energies, essen- tially engendering a many-sided competition at memorization and mimicking normative examples, displayed through diverse recitations and examinations;
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> » Implementing a suitable presentation of the culture through specially designed textbooks and related resources, a pre- sentation that stoked the competition and fit well within the educational time and place of the school classroom and schedule;
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> » Working out instructional methods that capitalized on the student's possession of the textbook, helping students with timely explanation to learn by reading, and monitoring their progress efficiently with group recitation;

» Instituting means of preparing adequately trained teachers who could manage the system and make it work; and

» Developing public polices, centering on material progress, social improvement, and political cohesion, that moved parents and the public to devote sufficient resources to sustain the educative effort.

These developments were tightly interrelated. The transition required the integration of complex factors into a functional system: the design of educational space and time; a chosen pattern of educational motivation; pedagogical materials suitable for use in such places with such motivations; methods of instruction suited to the organization of the cultural materials, teachers adept at using such tools and strategies; and arguments demonstrating that the substantial costs of it all were worthwhile -- all were simultaneously essential to the historic transition to mass schooling.

Sixteenth-century educational reformers worked out integration of these six, interrelated matters. For five hundred years, educators perfected, expanded, and developed the basic components of the educational system introduced early in the era of print, in due course creating modern systems of universal, compulsory schooling. As the degree of elaboration and penetration of the system into society changed, the specifics justi- fying the effort evolved to stay synchronized with cultural trans- formations. The main features remained stable, however. The design of the classroom and the organization of the school day, the motivational strategies employed, the scope and sequence of textbooks, the definition of good teaching practice, and the rationales for public support remained very stable. The reason for the underlying stability was rather simple: throughout it all, the character and limitations of printed textbooks remained substantially fixed, the keystone of the system.

We who inhabit the electronic ethos of the twenty-second cen- tury must remember that early in the twenty-first, the function of printed materials changed rapidly, becoming restricted to their current role of verifying and guaranteeing standard data sets when the electronic versions possibly could be altered. Before then, physically printed materials had a more central intellectual function. For five hundred years, books were the unmatched resources for making ideas, knowledge, and culture available to students, and so long as this role was unquestioned, educators paid little attention to how the characteristics of books shaped the whole instructional enterprise. But during the last half of the twentieth century, diverse innovations in communication and computation occurred, displacing books from their privileged educational position and creating our current, electronic means of access to cultural achievements.

From our vantage point, we can see how the microcomputer, and all its attendant peripherals, quickly matured into powerful multimedia systems. They thereby created a significant historical dilemma for educators at the end of the twentieth century. How were educators to make use of these new resources? Did the existing educational system comprise permanent, necessary arrangements? Should schools remain forever a system of classrooms for twenty-five children, of similar age and talent, overseen by a single teacher, learning set subjects that had been divided into lessons, competing for grades and recognition? Were these arrangements historically relative accidents, sensible in one communication context, but perhaps vestigial survivals in a new context, with distorted functions? In planning computer-based edu- cational efforts, what should educators take as givens that would remain stable, before and after the introduction of powerful infor- mation technologies?

At first, this question was not clear to educators. Early users of computers in education simply assumed that most features of the given system would remain stable, only getting better through judi- cious use of the new technology -- with a good deal of divergence, we might add, over what "better" might mean. There was an initial wave of enthusiasm, and a strong undertow of skepticism, and lots of ingenious, but encapsulated, efforts to incorporate computers into the educational system. Through such efforts to introduce computers into late-twentieth-century schooling, educators became increasingly aware that the then-existing practice was a complex technical system highly adapted over centuries to making use of books as the prime medium of cultural exchange. Encapsulated innovations repeatedly engendered inflated expectations and produced disappointment and disdain.

Unfortunately, the old system had spawned a huge establish- ment of educational research, which functioned to optimize tech- niques and programs within the given system. Almost all its methods for measuring results were system-specific: they assumed that existing divisions of subject matter were the appropriate domains for testing, that standard grade-levels were fit bases for norming results, and that verbalized information was the prime indicator of learning. The bias of such research helped to protect the existing arrangements from systemic changes.

To organize education to exploit the possibilities of an electronic media for cultural exchange, possibilities far more powerful and flexible than the printed media, educators had to rethink the system as a whole. They needed to take none of it as a given that would necessarily persist, unchanged, from before to after the in- troduction of computers. Further, to assess a new system, relative to the old, they had to develop a whole new type of educational research, one that did not presume, in its standards of testing and measurement, that structural accidents of the old system were educational necessities of timeless applicability. The full, fun- damental re-examination of educational options, and the methods for assessing them, began in the 1990s. It initiated the second historic transition in educational practice.

Looking back from the twenty-second century, the results of this re-examination are clear. Educators began to explore new solu- tions to all aspects of the existing system. They stopped applying computers to the educational strategies that had been developed in the early era of print. Instead, they started to search for edu- cational strategies that seemed sensible in an era of digital informa- tion technologies.

> » At the end of the twentieth century, educational innovators scrapped well-worn assumptions about the physical location of education, keeping the school, largely for reasons of so- cialization, but discarding the traditional classroom, opening it physically to make many different groupings possible, from the very small to the

very large. Likewise, they discarded assump- tions about the periodicities of school work -- the school day and the school year. Instead, they adopted very flexible scheduling strategies, which were among the many possibilities the new technologies facilitated.

» Educators harnessed a much broader mix of motivational energies than had been possible with print-based schooling. As sustained work by small groups became more feasible, cooperative learning became even more important than tradi- tional competitive learning. With that development, the edu- cational system began to function less exclusively as a sorting mechanism and more effectively as a means to engender social integration and interpersonal solidarity.

» Simultaneously, curriculum reformers profoundly changed the organization of ideas and knowledge, reversing the tendency to break the whole up into discrete domains of subject matter. With the old system, there had been a separate text for each subject and each grade -- the experience of study had been compartmentalized and sequential, with minimal access in any particular grade to the materials used in prior or coming years. The new organization substituted an encompassing organization of ideas and knowledge -- comprehensive and integrated -- for the sequence of graded texts. It also provided a variety of navigators, appropriate to different ages and inter- ests, to help the student. The result was most important: the experience of moving through the curriculum ceased to be one of a sequential study of subjects, grade by grade, and became much more one of a cumulative mastering of the cultural landscape.

Also with respect to the organization of ideas and knowledge, innovators made the indices for accessing ideas broader, more flexible, and more effective. In the era of print, keywords and a substantial acquisition of verbal knowledge mediated access to stored ideas and information. Even to find a picture, or later a film, one had to be able to read one or another sort of verbal listing. The new technologies greatly extended the power of multiple representation in the culture, and multiple representation had its most significant effect, not on how people received ideas, but on how they found them, activated them, and then apprehended them. Pictures, icons, sounds, and gestures came to rival written expressions as means of accessing ideas. With that change, the resources routinely usable in the curriculum blossomed -- pictures, films, performances, recitations, diagrams, graphs, animations, simulations, maps lost their merely "illustrative" character. People began to make arguments with them, to explain things through them, discovering how to give images apodictic, declarative, propositional power. We can now sum up all these changes: in our electronic culture visualization enhances the verbalization that characterized the print culture.

» As educators reorganized the culture, so too they altered the pedagogy guiding its study. The project method now came into its own and ideas about instruction gave way to those about construction. Students, usually working together in groups, would receive an intellectual charge, a large intellectual task that would occupy them for sustained periods of time. The curriculum could no longer consist merely of a series of lessons in a set of subjects. It was rather a field of information, ideas, and sets of tools, disciplines, and methods, by which students could bring information and ideas to bear on the charge, the task at hand. Educational method required the design of sustained, productive assignments, situating them in fields of knowledge and availing in these fields powerful tools that students would find usable in pursuing the charge their teachers had put to them. Thus learning has come to take place as students pursue various tasks, mobilizing fields of knowledge and intellectual tools, in the process learning by doing. In the old system, extrinsic contexts -- physical location and the school calendar and routine -- had done the real tracking of activity, but in the new, the curriculum had sufficient wherewithal built into it to keep track of precisely what parts of it each student had used at what times for what purposes. Well-informed in this way of their options, even young students were empowered to make decisions for themselves that teachers formerly had made for their pupils. The pedagogy became individualized and student centered to an extent never before possible. Educational strategies formerly associated with university level work spread throughout the schools.

» Concomitantly, educators also re-conceived the work of teachers thanks to the same features of the computer-based curriculum that made the learning of students cumulative. In the old system, teaching had been a highly repetitive profession, with few challenges to sustained self-development in it, for the material in the syllabus and in the text, year after year, had remained static. But the integrated, multi-faceted computer-based curriculum comprised an inexhaustible re- source that teachers could continue to explore with verve throughout their careers. As a result, in the twenty-first cen- tury, the profession gained significantly in stature.

» Soon, leaders in the profession and the public even devel- oped important new policy justifications for the emerging computer-based system. Formerly, the public had typically supported classroom-based education because they had perceived it to be a needed means to some extrinsic end -- religious salvation, political power, economic security. To be sure, the new computer-based system continued to be a use- ful means to such goals. But in addition, they developed two further elements in an important new civic agenda for education. First, they made computer-based education a significant means for addressing some deep-seated problems of equity. The new system worked well for a broader cross-section of the population because its resources were responsive to multiple forms of intelligence and learning styles. Second, as the culture became digitized, education became, in the eyes of most people, an end worth pursuing in itself. A strange split had long existed between entertainment -- held to be fun and amusing, but idle and small-minded -- and edu- cation -- considered to be work and laborious, but constructive and enlarging. With the new educational system, this split quickly disappeared. The consequence has been fun- damental: in the twenty-second century, most people generally rank educational opportunity, in preference to social security, national defense, or material progress, as the key benefit of civilization.

These developments took shape in the decade preceding and following the year 2000. Educators gave up trying to introduce new technologies into the established system and they thought out an alternative system, which ineluctably displaced the old one. They came to call it the Cumulative Curriculum, and one of its pioneers, the educator Frank Moretti, described it this way:

We seek to replace the superficial traveler through the sequential school, who collects knowledge trinkets to memorialize each stop on the cultural itinerary, with the philosophical explorer, whose very search for knowledge is a search for self and community. The word cumulative points to the growing personhood of the child. As the Latin indicates, it is a "heaping up" within. Able to instantly access the totality of his work through time, the child has control of his intellectual history as a series of understandings rather than the usual cryptic external judgments symbolized by [grades]. Accordingly, a child need not see each year as a separate beginning but rather as a continuation of a substantially accumulated educational reality, which is his currency entering a new year. The challenge for the child is to understand his rich past and to plan a series of strategies for moving to the next stage. He chooses his educational future in the context of the world within him that he has already shaped and formed. In this context, adults have to give up the security that comes from pretending to know precisely what it is that children ought to learn, by year, by subject. . . . The child begins with his own rich world, which is the starting point of all inquiries. . . . He understands that the art he will master is that of the tentative hypothesis, the value of which is determined by the degree to which it has to the power to explain. What the student of the cumulative curriculum will perceive as "learned" are formulations whose parenthood is not in doubt. Clear about his ownership and authorship, he will perceive all that he knows as the immediate horizon of his all-too-human vision and will seek to extend it, to glimpse a new world and form new understandings that embrace the old.

Once tried, this effort to help student's take possession of their own learning, to "heap it up from within," succeeded rapidly. Old sequential school systems, which had seemed impervious to change, rapidly adopted the cumulative curriculum. Since its initiation at the turn of the twenty-first century, of course, the new system has evolved steadily, more and more thoroughly displacing the vestiges of the print-based educational system. The results have been liberating and profoundly progressive.

Democracy, which had been, for the most part, a predominantly political development through the twentieth century, has gained a substantial cultural import. The persistent tendency of print-based education to reproduce and accentuate differences of power, privilege, and wealth has been decisively reversed. The digitization of the culture has been thorough and with it participation in its full powers has been decisively broadened and tools that strongly amplify human powers of calculation and control have become accessible to nearly all. The great twentieth-century aspiration, verbalized by John Dewey through Democracy and Education, has become substantively fulfilled, although in an environment of pedagogical practice quite different from any he could then imagine.

Shortly before the year 2000, a long era of international tensions and war, in which national defense had been the prime function of the polity, ended. Peoples of the major nations turned their energies more fully to nurturing their human potentials. The relaxation of tensions coincided with the development of the new media of education. Liberal reformers regained a sense of their efficacy and people became increasingly confident that they could at last solve the long-standing human problems of industrial democracy. As the third millennium began, the idealistic conviction of some, that each person has a stake in the welfare and fulfillment of all, deepened into a general common sense. Material conditions and cultural convictions converged to provide the historical grounds for the worldwide educative polity.

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Our informant from the future depicts an alluring vision, one that we may be tempted to dismiss as too optimistic. But these are times of extraordinary potential and extraordinary change. Educators should not face them blindly, recapitulating past expectations and assumptions. However solid seeming, our educational structures are historical creations subject to thorough transformation through the subsequent dynamics of continuing historical change.

Our informant from the future draws our attention to the need to look at the whole educational system in considering how to introduce information technologies into it. A basic proposition provides the generating principle of this essay: in order to have substantial effect improving education, the digitization of our culture will need to elicit a full systemic innovation in education, one that changes not only the medium of cultural exchange, substituting digital code for print, but the entire educational context for working with that medium.

In the chapters that follow, I advance a case that systemic innovation in education is both desirable and possible. I do so by essaying answers to some large questions:

> » What significance for cultural history do computers have?
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> » What historic imperatives should educators recognize as fit measures for the worth of their work?
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> » Would widespread adoption of information technologies enable educators to meet those imperatives more effectively than traditional schools have?
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> » How should educators, who want to develop the potentialities of technology in education, deal with the pedagogical environment, motivation and assessment, the organization of culture, pedagogy and educational method, and the role and preparation of teachers?
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> » What civic agenda for education should guide efforts to achieve the pedagogical potentials of digital technologies? Each chapter successively addresses one of these questions. The chapters follow sequentially, but they reciprocally interact and hence their true sense inheres in the cumulative whole.

Chapter Two - The Computer as a System

Computers are like wheeled vehicles: they come in many shapes and sizes, each serving a different purpose. Moreover, the computer has yet to mature. It is an emerging technology. Hence, to determine the potential of computers in education, we need to understand what the computer is. To start, consider two distinctions, one between transitional and mature technology and the other between artifacts and systems.

Complicated technologies take a long time to develop their potentialities. They also take capital. Developers cannot perfect their technology in endless years of laboratory work and then deliver it, refined and complete, to a grateful public. To underwrite the costs of perfecting a technology, developers must bring it to market long before it is mature. Profits from transitional implementations sustain the development work, providing resources and disclosing unexpected opportunities for use. Computers have exemplified this drawn-out development: computers have evolved through several distinct, quite profitable incarnations, yet neither the time-sharing mainframe nor the stand- alone micro indicate fully what the computer will be when the technology matures.

In common speech, we generally do not distinguish between typical technological products and the technical systems that make them usable. For instance, "television" can refer to the TV set, that ubiquitous appliance, or to the whole industry -- the networks, their broadcasting installations, the news teams and production studios, advertisers, and all. Likewise, "automobile" can refer to the car in my driveway or to the vast infrastructure -- the manufacturers here and abroad, with their suppliers, advertisers, and dealers; all the roads and bridges and the builders constructing and maintaining them; the service stations and oil producers, refiners, and marketers; and the myriad of designers, workers, police, and service people who make the system go. The car is both a separate artifact and a complex system.

Currently, "computer" usually calls to mind the artifact, the stand-alone personal computer, like the one on which I am now writing. Most of us do not think much about the complex system of which my PC is a transitory part. Computers as a system are important, however. The significance of computers for education will not be well understood by thinking simply of a lot of separate machines sprinkled through existing schools and colleges. Computers are an emergent infrastructure, a system, fully as complicated as that of the car. We need to think about what that system is and how that infrastructure will work. Computers as a system can be a powerful agent of change in education.

To grasp the computer as a system, particularly as it matures, let us concentrate, on neither hardware nor software, but on an underlying process, the digitization of information. The computer, as a system, introduces a new way of representing information in our culture, a new way of encoding ideas. When complete, it will constitute a deep transition in our history, one equal in importance to the introduction of printing, quite possibly to the development of writing itself. Essentially, the computer as a system will envelop all previous modes of representing information, preserving and empowering them by integrating once separate domains of communication into a unified, "multimedia" system.

Information in Matter and Energy

Think of the ways we commonly represent information -- a scribbled note, a neatly printed page, a reflective sign, a painted picture, a ruler uniformly marked, a measuring cup, or the symbolic forms of church or court. With these, people have encoded ideas and information in material objects, in the ink upon the page or the shape of the sculpted stone. Put most generally, through traditional ways of encoding ideas, people expend energy to transform matter in ways that they will find meaningful, making enduring marks and forms in which ideas inhere. People locate the information in the material object. When they do this according to a defined convention and art, the tangible, palpable results are our major forms of traditional communication -- documents, sculptures, pictures, monuments.

Starting with the telegraph and developing through the telephone, radio, television, and computer, people have begun to put their information into controlled pulses of energy itself. The material object, say the telephone, becomes a kind of transparent medium for an infinity of possible conversations encoded in different electrical waves that the phone will generate, transmit, and receive. Increasingly people are representing information in controlled states of energy, not in matter, as they did traditionally. The new practice requires various material tools, with which people apprehend on their human scale the information located in energy, but the information is not in the material, but in the energy. Thus the TV translates the information bearing energy into a material form that I can watch. The picture hanging on my wall is what it is because the information that it contains is in the material that makes it up. My TV, in contrast, can receive an infinity of images because the information it displays is not in the material of the set, but in the electromagnetic waves that it picks up and decodes for me.

This practice of locating information in energy states is not entirely new in our culture. One can take sound to be a form of energy, not a state of matter, and hold that through speech and song people have long encoded information in energy, using the ear as the naturally developed, material receiving apparatus. Other senses, too, especially sight, kinesthesia, and the ability to feel hot and cold, derive much information from energy states and forms of force. Some traditional tools of communication and control also provided readings of the information in energy states. The clock measures time by controlling the release of energy in uniform units. The compass provides a most informative reading of the orientation at any location of the earth's magnetic field. The governor on a steam engine directly translates a change in its energy state into a controlling action. Like the TV -- but unlike the painting on the wall -- clocks, compasses, and governors all inform their users through their changing readings, not through their static states. More strictly speaking, these instruments display information that is fortuitously located in states of energy, rather than encoding it in those states. Traditionally, only the voice and musical instruments went beyond display to encode.

Up until very recently, information encoded in energy has been, however useful and dynamic, troublesomely transient. Speech is the paradigmatic instance. It is powerful and nuanced, yet fleeting and unstable. For a time memory preserves its residue, and writing fixes a stiff representation of it in stable matter. But much is lost. This transience also characterizes many modern media that encode information in wave forms, substituting electricity for sound as the energy medium. Thus telephone, radio, and television have enabled people to encode sound and gesture in electromagnetic waves, amplifying these vastly, without making them much more enduring. Recording signals on tape and other media makes such material reproducible, and thus enduring. Yet this has been a recent, ancillary development. So far, the power of electromagnetic media has resulted from the breadth of their transient reach, not from the ease with which productions can be reproduced.

This transience of electromagnetically encoded information fundamentally affected the usefulness of broadcast media for education. Entertainment results from encountering cultural experiences for their immediate, present value -- they amuse, inspire, absorb, purge, distract, or release us now. Education involves us with cultural works of enduring importance -- we acquire skills, ideas, beliefs, knowledge, information that will empower us over time in the conduct of life. The things at stake in education are the elements of the culture that are on-going, lasting resources. Consequently, the educationally important media are the ones that represent and make such enduring ideas and skills available to people. For the most part, these have been the media that locate information in material objects, particularly in printed texts and pictures.

Commentators complain that educators have done little with the major communications developments of the twentieth century. Despite high hopes, radio and television have not become important educational resources and some infer therefore that education is resistant to technological change. This inference is wrong. The photograph, which extends the pictorial capacity to locate information on film and paper, has been seamlessly incorporated into education. It improves the capacity to work with lasting ideas and information, and educators have quickly adopted photographs in the processes of research and instruction. As conservative a field as art history took without hesitation to 35mm color slides because they served the intellectual needs of the subject. So too, recorded music has become a natural part of music education, far more so than have broadcast performances, for the recordings are stable, enduring resources that different students at different times can study, each with unique purposes in mind. Recordings suit the needs of education because they are stable, easily stored and retrieved, while broadcasts suit the needs of entertainment, absorbing us in their immediate presence.

Educators cannot resist new technologies, provided those technologies have characteristics suitable to educational purposes, foremost among those being a permanence in time. Stop for a moment to consider film, which encodes information in stable, material form yet has not come into robust use in education. Is it an exception to the rule here propounded? No. With respect to dissemination and retrieval, film is not as stable as it might seem. Film is bulky, hard to store, costly to project, and easily damaged. It can be best disseminated in a quasi-broadcast fashion with prints distributed to numerous theaters more or less at the same time, with the production playing as long as it can command a full audience and then disappearing into an archive, from which films are not easy to retrieve. These distribution constraints have made movies, until very recently, far more effective as media of entertainment than of education.

Computers as a system will change that, and much more. Broadly speaking, the communication innovations since the mid- nineteenth century have created a family of technologies for encoding diverse forms of information in energy. The computer is the most recent in this series of innovations, and it is likely, historically, to incorporate all those leading up to it into itself. What seem to us to be separate industries with separate technologies will become branches of a single comprehensive industry and technology, the computer as a system.

One can now see large corporations jockeying to capitalize on this consolidation of technologies. For instance, the major Japanese electronics firms seem to be calculating that they can best shape this process by combining business communication with the entertainment industries, buying up major entertainment conglomerates while designing ever-more computing power into home entertainment devices. The emerging system, however, may in fact be far more robust if built on a combination of telecommunications and education. Digital technologies enhance the staying power of information in time, expanding its educative power relative to its currency as entertainment. We will be developing the thesis that the computer is rapidly incorporating the modern media in one comprehensive system, a system of knowledge and education.

The Analog and the Digital

We distinguished between technologies that locate information in matter, for instance sculpting and printing, and those that locate it in states of energy, for instance radio and computers. Among the latter, we need to make important further distinctions, which have to do with the techniques people use to encode information in energy. To grasp the cultural import of the computer as a system incorporating all the media of communication, to appreciate its potential power, we need to reflect on the way that it encodes information in energy, seeing how that differs from other techniques.

Analog coding serves effectively for some specialized computational purposes, but almost all computers, from tiny palm- tops to huge supercomputers, work with information stored in digital code. Such digital code differs profoundly from the analog codes used typically in radio and television. In the paragraphs that follow, we will reflect on how digital code differs from analog and then consider five matters that determine the value of information for human activity -- production and reproduction, storage, transmission, selective retrieval, and intelligent processing. Through these considerations, we will form a sense of why the computer, as it matures, will be a very significant step in our history.

Note at the outset that we could apply this distinction between analog and digital coding to the media that use matter to carry information. For instance, painting and sculpture are highly analog media, whereas alphabetic writing is interestingly ambiguous. It is analog insofar as it is phonetic and digital insofar as it is a prescriptive set of legible conventions. But it would take us afield to pursue these distinctions with respect to media that locate information in matter, for our concerns here are primarily with the media that carry information in energy. How does the digital coding of information in energy differ from the analog?

Analog systems encode information in energy by using the properties of continuous waves so that each successive change in the amplitude of the wave will be analogous to a change in sound or appearance in the human world. Lets construct an example. Take a dishtowel. Holding each corner of one end in each hand, flap it rhythmically in front of you, making it undulate up and down. It is not hard to control the beat of the flapping, making each flap identical in duration, perhaps slow and long or quick and short. That beat is like the frequency of an analog signal. Usually it does not carry the information, but when we are surrounded by many different signals, each with a different frequency, it allows us to find the one signal we want. Observe the flapping towel, however. From beat to beat, it will have all sorts of variations, curving this way then that, depending on subtle changes in the orientation of your hands to each other and the tension they put on the cloth. If you could control the flapping skillfully enough, you could make each change in the way the towel undulated match some other, analogous change in a completely different wave, say the ever changing sounds of a symphony or rock concert. At that point, you would have encoded the concert in the flapping towel rather like the way radio encodes a concert in an electromagnetic amplitude or frequency.

Like the sound itself, the flapping is transient. Analog encoding depends on making significant changes in the energy state of the wave, a most unstable phenomena. Digital encoding is much more stable. Put down the towel and flip the light switch on the wall. The switch has gone from "on" to "off;" it was stable in its former state and is stable in its latter. The light switch is a digital device, although one that does not accomplish much in the way of communication and control. To see simple signals controlling more complicated processes occurring around you, look at another digital switch, the stoplight at the corner. It has two basic states, red or green -- amber is not really a state, but a cue that a change of state is about to happen. There are two unambiguous states, green-go, red-stop. These are easily standardized, stable, and remarkably effective in controlling complex flows of matter and energy. The stoplight is very much like the small charge in a transistor in that one state allows traffic to move and the other calls it to a halt.

Our basic red-green stoplight is a binary digital system -- binary because there are two alternatives and digital because those consist of discrete, unambiguously different states. The typical electric stove, with options on each burner running from warm to high, has a quinary digital control on its coils -- quinary because there are five alternatives and digital because each of these is distinct from the others. Thus, digital systems can in principle have different numbers of basic alternatives, but computers almost always use a binary system, building many subtle variations from a multiplicity of either-ors.

A digital state is what it is, discrete, unambiguous, disjunctive. Digital code does not capture changes similar to other changes, it presents a set of values that are what they are. Digital coding follows a principle akin to encrypting -- there is only one message, which, when encrypted, is put in a way that makes it look indecipherable. With the appropriate key, however, the cryptographer finds the message, not something like the original, but the original itself. For instance, the apparatus for recording music digitally measures sound frequencies at successive instances and records the numeric value of the frequencies. These are samples of the actual sound, not likenesses to it. Digital coding samples a phenomenon, registers the sample, and then reproduces the phenomenon from the sample. If the sampling technique and the technique of reproducing from the sample are very good, it can be extremely hard to distinguish the original from the reproduction. What is coded is an exact value, precisely what it is and nothing else.

What is encoded digitally, therefore, is actually very different from what is encoded in an analog system. The digital system encodes a sample of the thing whereas the analog system encodes an analogy to it. Again, let us construct an example. Consider a full wheel of cheddar cheese. Describing the cheese by analogy can be difficult. I might say it is about the size and shape of an old-time hatbox and that it is heavy, as if the hatbox were filled with water. Its color is like custard and it tastes -- this is the important, difficult part -- somewhat like grapefruit, although its texture in the mouth is very different, a bit like a firm fudge that crumbles and then softens into a paste as one chews it. Describing the cheddar by a sample of it is much simpler. I cut you a little piece, perhaps several from different places in the wheel. The sample is the cheese and you can sniff it or taste it directly from the sample.

When we digitally code the sample, we register what the sample is on an appropriate scale and we code that value, not some approximate likeness to it. Consider recording a singer's voice digitally. At numerous intervals the recording samples the exact sound frequency of the voice, registering in a matrix of precise values what, at each sampling instant, the frequency was. The digital recording carries no information about the voice during the intervals between the sampling instants, but it carries the exact frequency of it at those instants. If the sampling frequency is sufficiently rapid, the sound of the reproduced voice will be essentially identical to the original. Digital code allows the playback to reconstruct the voice. Thus, digital coding registers sampled values, not approximate similarities. That is its first point of difference with analog coding.

Secondly digital code differs from analog because it resists degradation far more effectively. Electrical systems, like everything else, are subject to entropy. Every circuit has in it random fluctuations. Computers are not wondrously free of such static. Minor fluxes are a big problem in analog coding because the locus of information is in tiny incremental differences in the amplitude of waves, which the random fluxes in circuits can easily affect. In the absolute, digital systems are equally subject to noise, but the locus of information is in the basic energy state, not in small changes of that state. When the significant point is simply whether a circuit is on or off, it allows for a huge threshold before an intrusive fluctuation will become significant, making a circuit that is "on" appear to be "off" or vice versa.

To construct an example, consider a binary test for whether or not it is raining: looking out my apartment window to see if the sidewalk is wet or dry. This test is subject to noise -- perhaps in this case we should call it "splash." During the summer window air-conditioners in the building adjacent condense water on hot, humid days, splotching the sidewalk. Also on the road on the other side there is a low spot where water collects from a leaky hydrant and occasionally passing cars splash it onto the sidewalk. Like the noise in the electrical system, extraneous wetness sometimes partially covers a dry pavement. This rarely confuses my binary test, however, because I establish a threshold -- it is raining if the sidewalk is fully, uniformly wet and it is not raining if the sidewalk is dry, or partially splotched from random sources of water. Given the substantial threshold possible in a binary system, very, very rarely will electrical noise cause the misreading of a bit of information.

In sum, in comparison to analog coding, digital code registers values that are attributes of the thing being coded, not likenesses to it, and those values, once coded, will be remarkably resistant to error or degradation. These characteristics make digital code immensely useful in processes of communication and control.

Digitization and Communication

Digital code records samples of phenomena, not analogies to them, and it does so by techniques that are remarkably stable and accurate. By themselves, these characteristics may not seem so extraordinary. But put in context, the context of human use, they have very significant effects on the computer as a communication system. Whatever the medium, in order to communicate people need to be able to produce and reproduce information, to store it, to transmit it, to select among it, and to process it intelligently in the course of action. These five areas determine the relative historic value of different communication techniques. Reproduction, storage, transmission, selection, intelligent action: communication techniques that perform these functions well serve human needs well. Because digital coding registers samples of things and because it resists error and degradation, it has interesting effects in each of these five areas. These effects will determine how the computer as a system can contribute to our unfolding cultural history.

We begin with the problem of producing and reproducing information. What sort of information can one produce with a typical analog medium, audio tape, for instance? The answer defines a wide range of matters -- anything that can be recorded through an electromagnetic analog to sound within certain frequency ranges -- an aria but not a painting, a speech but not a balance sheet. The analog techniques used in the audio system must be closely coupled to the phenomena they record so that the way they modulate electromagnetic waves is precisely analogous to the particular wave patterns they are recording. To use the audio system to record images or the financial transactions of a bank, complex and careful adjustments need to be made in it, radical adjustments that convert the audio system into something quite different. Here the constraints of the analog medium limit the sort of information the system can record. With the digital system, we can produce a much more flexible range of information. As a result, digital coding can absorb both the analog media for carrying information in energy and many of the more traditional media that carry information in matter. For instance, the most familiar digital application now is word processing, enabling people to manipulate electronically the material system of writing with far greater flexibility, precision, and ease that traditional means have availed. In due course, anything that we can represent with a symbolically coded sample, we can record in a digital system.

It is not a trivial task to implement this potentiality. But it is inexorably happening. The first wave of computer uses involved diverse numerical applications. The microcomputer extended these and added extensive textual applications. Recently software designers have incorporated two-dimensional graphics into many programs for general use and three-dimensional imaging for special needs. Supercomputers have begun to record vast samplings of extremely complex phenomena that were simply beyond the ken of analog media -- climate change and molecular structures, for instance. With compact discs, the audio industries have developed and marketed the digital recording of sound, which is fast being incorporated into computing systems. The television and computing industries together are rapidly generating digital systems for producing and recording moving images. Techniques for sampling nearly all the forms of information and capturing them in digital code are quickly developing. In its basic sense, the concept of "multimedia" is this practice of integrating in one system all forms of producible information. When we speak of the computer enveloping other media and incorporating them into itself, we mean the capacity, unique to digital coding, to produce and reproduce many different forms of recordable information. Multimedia implements this capacity.

The difficulties in implementing multimedia are not primarily "technical," in the layman's sense of the term. Ordinarily we think that the technical problem lies in designing an apparatus to accomplish a novel purpose. In many areas, making the apparatus is relatively simple, and it can be done in numerous different ways. What is difficult is setting a controlling standard that will establish agreement on which one of the possible ways to design the apparatus will be the one put into common use. This is in part a question of technical standards -- for instance, what sampling rates will be standard for digitally encoded sound or what screen resolution will be standard for digital high-definition television (HDTV)? But the problems of controlling standards goes far beyond the domain of technical standards -- long established branches of law and language are at stake as well.

Thus, the production and reproduction of information is not simply a technical process. It is a process controlled by law and driven by incentives. Digital coding of information will affect these domains as well. For instance, copyright makes sense in a system in which people locate information in material objects -- copying consists in expending the energy to implant the information in matter, preeminently by putting ink on a page. Copying information that is located in matter is a laborious, error-prone process, subject to legal processes. Recording and reproducing information that is located in energy has very different characteristics. It becomes extremely inexpensive, with the result that it can be done ad hoc by anyone who possesses easily available, inexpensive tools. Already, spontaneous reproduction through analog means, such as photocopying and audio and video tape, has put considerable stress on laws pertaining to the right to copy. The broadcast industries have had to develop novel ways to realize economic benefit from cultural works, ways that turn less on the right to copy and more on the right to use a work.

With digital coding the reproduction of material becomes even faster, cheaper, and vastly more accurate than it does with analog electronic media. Once something has been sampled and captured in digital code, the idea of a copy of that sample ceases to make much sense. The copy is not really a copy, but a second instance of the original. The computer radically changes the conditions bearing on the reproduction of information and ideas. Once the infrastructure is in place, the reproduction of materials has a negligible cost with respect to materials, work, or quality. In principle, in a digitally encoded culture, anyone can have instances of anything they wish without added cost to the system. It will require an elaborate process of technical, social, and legal development to achieve actualize such potentialities.

Digital coding will also transform the problem of storing information. Librarians concerned with the preservation of materials traditionally attend closely to the durability of paper and its possible substitutes. The key question they ask is: "How long will it last?" This makes a lot of sense as long as the information is located in matter. If the paper will quickly degrade, the cultural community will soon need to reprint its materials or reproduce them on some alternative material such as microfiche. The shelf-life of all this is important as each cycle of reproduction is very costly, as well as an occasion for material to be lost and errors in reproduction to creep in. With digitally coded materials, shelf-life remains limited, but the costs of reproduction and the likelihood of errors arising from reproduction drastically declines. Hence, the keepers of the heritage need to rethink the standard principles of storage and preservation. Continuous reproduction can make the quest for durability unnecessary. Since reproduction is very cheap and very accurate, the problem is not one of finding the most enduring materials and keeping them as stable as possible. Rather the problem becomes one of regularly refreshing the energy-states in which the information is located and making sure that it is scattered in enough separate instances that a catastrophic failure in one instance would not obliterate the heritage.

Other, more novel problems of storage also arise. With respect to information located in material objects, we naturally store materials in institutions adapted to the attributes of the objects. Thus we use libraries for books and museums for paintings and artifacts. Much intellectual specialization arises because people need specific skills to work effectively in these different collection of material resources. Insofar as we can record all these resources in digital code, we will store them in one, comprehensive system and we will thereby diminish in power many objective goads to intellectual specialization.

As digital coding makes information easier to store with much diminished threat of loss, so too it improves our ability to transmit information. Transportation costs and limitations have long been a significant determinant of communication capacities. Through the twentieth century, techniques of coding information in energy have greatly reduced the costs and limits on its transmission. With the substitution of digital for analog coding, these developments are extending far further as we enter the twenty-first century. Analog systems using energy as the medium have developed two major principles: point-to-point circuit switching, as through the telephone, and the use of wide information channels in broadband transmissions, as through radio and television broadcasting. Digital systems are combining and unifying these two principles, allowing the links between point-to-point switched circuits to be wide information channels, creating a single transmission net of extraordinary flexibility and power.

We are already everyday users of the basic principles essential to these changes. My mother is eighty-eight and legally blind, but she can use a push-button phone with confidence and has a good head for phone numbers and thus she keeps up familial and social connections all over, in Mexico, in Canada, and around the United States. Each time she dials someone's number, she instructs the phone system to establish connections within its circuits to link her phone with that of the person she is calling. Phones code and decode voices from a very simple electrical signal that can be easily transmitted through complex switching systems and has a narrow band for coding information, one just sufficient for the low- fidelity reproduction of ordinary speech. How much traffic the phone system can bear depends on how many separate circuits it can switch together at any time and on how many separate transmissions its trunk lines can aggregate together in simultaneous calls. You'll get a busy signal if the system runs out of switches or transmission room.

Radio and television use much wider bandwidths, and they code them more intensely, with the result that their signals can be much more complex than those of the telephone. Thus radio can reproduce sound with much greater quality that the telephone, and the amount of information transmitted via television far exceeds that used in a phone conversation. The wider bandwidth, however, makes point-to-point switching in such transmissions more complicated to do without introducing noise into the signal, and without overwhelming the capacity of connecting circuits when many parallel transmissions are traveling on them simultaneously. Various properties of digital coding facilitate the combination of circuit switching with the information intensive transmissions that characterize broadband systems.

Both analog and digital systems make use of what we will call micro-time, the actuality of incredibly brief instants. For instance, radio waves fluctuate several million times per second and each fluctuation produces some of the information we hear. The higher the frequency, the more information the signal can contain, provided we can keep the receiver tuned to the proper spot upon the spectrum and provided we can minimize interference between signals and other sources of noise. Because the information bearing medium is a continuous wave, however, we find it much easier to propagate the information onto the medium at the rate it occurs at, and at which it is to be received. In contrast, when the information has been captured in digital code, it becomes much easier to make use of micro-time in more flexible ways: capture, transmission, and delivery can be separated. The pace of capture depends on the pace of the phenomenon, what we call "real time." Transmission of the binary units, the bits encoding the phenomenon, can take place in different time -- it can squeeze into each tenth of a second, or less, the information needed for one second of conversation, giving the circuit to other conversations for the remaining nine-tenths, or more, of each second. By this technique, and others like code compression and error correction, the capacity of a circuit carrying digital data can be greatly expanded.

Further, the transmission of analog data depends very closely on the particular characteristics of the transmitting medium. With the transmission of digital data, it does not matter what the transmitting medium is, provided that medium has been adapted to transmit digital code. Thus all the different electromagnetic transmission media in common use now easily transmit digital data. More importantly, new media, useless for transmitting analog information, for instance, laser light in fiber optic cable, increasingly transmit digitized information with significant gains in speed and volume, at lowered cost, and with increased dependability. The frequencies of light waves are much higher than those of electromagnetic waves. Hence, we can pack information far more densely per unit of time into light for transmission over fiberoptic cables than we can with electricity over wires or electromagnetic signals in space. The usable bandwidth is much, much wider. The higher density allows much more intense timesharing of the circuit and the greater bandwidth means that in each instant a much larger load of information will be charging through the circuit. As a result, a system is emerging in which all forms of information -- text, numerics, graphics, audio, video -- can be transmitted, switched from point-to-point, as easily as we can with the phone.

Digital coding, thus, is making possible the use of one system to produce all forms of information, to reproduce anything in the system with low cost and little loss, to provide for its indefinite storage through this process of continuous reproduction, and to transmit any element of it to any user fast and cheaply. By themselves, these developments make oodles of good information easily accessible, threatening to overwhelm the user in a vast babel of bits. These three characteristics are of a piece with each other, setting limits on what intellectual resources a culture can provide its members. But they do not, alone, make for a well developed system of communication.

Selective retrieval, enabling people to get precisely the information they want and when they need it, has always been a key problem of culture and communication. How can you get from the culture the ideas and information that you want and need? And even more perplexing, how can the culture intimate to you and everyone else what possibilities of interest it does and does not offer in the infinity of circumstances surrounding us? Retrieval is a fundamental problem of all cultures, and it is becoming an even more pressing problem with digitally coded information. It is the fourth determinant of communication effectiveness in history and the widespread digitization of information is transforming it as well.

Throughout history, major communication advances have brought with them new ways to retrieve information. The practice of citing books and articles by title and author, edition and page, rose to full significance in the era of print. The printed book, which could be distributed in many locations in identical versions, needed some logically effective technique of reference and recall, one that would work in many different places and many different times. Prior to that people referred far more vaguely to an author and an argument or thesis, and to retrieve the actual text a scholar needed to know where a specific instance was physically located, with diverse works bound together for convenience. Today, people often handle their personal libraries in this pre-print fashion, jumbling certain books together say by size, or just shelving them as they come, able to find any particular one, not by a sense of logical order, but by having a feel for where it is by some sense of spatial juxtaposition. That works for small libraries, but it spells chaos for large collections of printed books. For those, people needed to develop far more systematic techniques of reference and recall.

With digitally coded information, the situation is much the same: people need to master new, more powerful retrieval routines to manage the cornucopia of information. These techniques relate to two different problems in the use of information -- exchanging information and applying ideas. In both exchanging ideas and applying them to problems, people need to retrieve information selectively. Exchanging materials is somewhat similar to the phenomena of point-to-point switched circuits while applying them is related to finding a station or channel in broadcast communication. Exchange requires the precise identification of start and end points and application requires the substantive sifting through extensive materials to select out the precise components pertinent to the problem at hand. Since the problems and prospects in each domain are rather different, let us consider each briefly in turn.

Our means for managing the exchange of information have already been heavily influenced by characteristics of digital coding, at least insofar as digital coding involves discrete units, as distinct from continuous waves. For instance, integer numbers are a system of digital entities: each number is discrete, autonomous, separate from any other. So too is the alphabet, which is a more restricted set of discrete elements, most simplistically twenty-six, but preferably 256, if we take extended ASCII code as the norm. Long before computers, people became adept at using numbers and letters to assign precise locators to all sorts of objects, persons, phones, buildings, accounts, parts, and so on.83 Implementation of these coding principles in digital computers enhances our capacity to manage them greatly, extending the scope, precision, and speed of the process. In substance, the problem of addressing things so that information about them can be exchanged from point-to-point is less technical than socio- political: the problem of privacy, of censorship, of deciding what limits, if any, to place on the reach of possible exchange. Whenever the power to exchange information increases significantly, it brings such problems with it. The abuse of privacy thus seems to be a structural issue, occurring at the margins where new ways to manage exchange are developing. Historically, people seem to opt for accepting the benefits of new systems of information exchange, after instituting measures to ensure that they will not be used to subvert personal security and integrity. Unfortunately, this trade-off has not always been benign as the tragic abuses of totalitarian regimes of right and left repeatedly demonstrate. As computers make it possible to exchange information that was formerly "private," easily kept to oneself, we will need to face up to difficult issues of defining limits and controlling abuses.

Retrieval that involves sifting, selecting, and applying ideas presents different problems and opportunities. Our existing techniques for doing this involve time-consuming secondary processing of materials -- indexing books, abstracting articles, cataloguing things under key words and subject headings, adding captions to pictures and tables, annotating works with cross- references and footnotes. Digital coding makes these practices more effective in three significant ways. First it facilitates the processing by creating tools to help people to index, abstract, caption, and catalogue their culture. This presents us incremental gains. Second, it makes many traditional references, which had been unidirectional from one work to another, usefully bi- directional. Only where very special indexes have been laboriously developed can I go into a library and ask for a list of works that cite a passage that specially interests me. In a digital environment, the electronic reference that implements a note will point both ways, something that will make traditional references useful in powerful new ways. Third, traditional references implemented digitally will save users much time and energy, for following out a reference will be nearly instantaneous. Currently it is often hard to maintain a train of thought in following a reference as one needs to go off to the library or bookstore, perhaps having to wait weeks for a work to arrive from a distance. Digitally coded links will be fast and transparent. Together, these three changes will significantly enhance traditional resources for the reflective retrieval of ideas and the application of them to our controlling purposes.

In addition, new retrieval resources are under development. These require no intelligent pre-processing of materials aside from the capture of them in digital code. Instead, the end-user of the material specifies criteria of interest, and the system matches materials in it against these criteria, showing the resultant possibilities and allowing the user to further winnow the results, should that be necessary. These principles have been most fully developed with respect to the retrieval of textual materials. Their novelty still engenders some confusion, and many people, among them even professional librarians, misuse the concept of "full-text retrieval." Thus some think it simply means retrieving for an inquirer the full text of a document, rather than an abstract of it. More properly it means conducting the search for matches to an inquirer's criteria of interest against the full-text of everything in a collection, rather than against a list of keywords. Techniques for such full-text retrieval are becoming both sophisticated and fast, and users can apply them to both the flow of current information generated through correspondence, calls, and news, as well as to libraries of accumulated information.

Techniques of search and retrieval have historically developed far more fully with respect to text than with other forms of information. Up to now, we use text to catalogue most other forms -- maps, pictures, numeric tables, films, recordings, and so on. Yet text processing is not the only form of intelligent recall and retrieval that we can do. We can often find our way to places with a visual- spatial memory that is much more effective that verbally forming a set of directions for ourselves. We associate both moods and ideas with various sounds and melodies and even colors and places. All this suggests that beyond full-text retrieval, there lies the domain of "non-text retrieval." In non-text retrieval we might point to a geometric relationship and request the computer to search a graphic database for other instances of the similar relation or play a chord and have the system call up musical compositions in which it occurs. Non-text retrieval should in principle be possible with digitally coded information, but for the most part it is a possibility that awaits development.

One area in which non-text retrieval has been underway for some time, however, gives an idea of its potential power -- statistical processing. Statistics can be thought of as a numeric system for selecting and retrieving information that allows for judgments of significance and relevance that are very hard by textual means alone. Also, the ability to zoom-in and zoom-out to different levels of detail on graphical materials such as maps, diagrams, and photos provides substantial non-text retrieval capacities. In general, digital code enables us to capture and link different kinds of information pertinent to complex phenomena and to represent their interactions in ways that we can see or hear, using those senses to select directly between combinations. All sorts of complex controls work this way, especially in simulation systems and innumerable computer games.

These variations on non-text retrieval really carry us into consideration of the fifth area in which digital coding is deeply influencing our culture -- the intelligent processing of information. For the most part, up to the twentieth century, communication tools used external artifacts to extend the memory, while leaving the intelligent processing of ideas to take place almost exclusively inside the human body and brain. Through cultural history, people have accumulated vast stores of memory projected outside themselves into man-made objects. Despite all that externalization of memory, the possible agents for the key verbs describing intelligent operations on information and ideas are still almost exclusively human person -- perceiving, sensing, thinking, correlating, inferring, deducing, concluding, and so on. With the computer, man-made objects are becoming useful in performing these intelligent operations.

Memory, to be meaningful, must ultimately return to a sentient human mind -- a library unread is not a culture preserved. In externalizing memory into material objects, humans have not alienated memory from ourselves, but enhanced our capacity to remember by transferring parts of the task to objects that we make and manage. So too, in externalizing intellectual activity, we do not entirely alienate it from ourselves. Instead we compensate for limitations, strengthen capacities for demanding operations, and enhance attention, precision, finesse, or speed.

To understand how the computer is accelerating the transfer of intelligence to external tools, it is important to realize that this is not a sudden novelty in our culture. We perceive the world with our senses and prepare it for thought: through most of history, people did this without the aid of instruments. That began to change some centuries ago. We can interpret the rise of modern science as the intellectual fruits of externalizing capacities for perception into instruments of observation. Clocks and chronometers permitted people to perceive time with ever greater precision. The telescope and microscope enhanced the human capacity to see distances and details. The thermometer lent accuracy to our capacity to perceive differences of hot and cold. Exact scales and rules and other measures, tuning forks, prisms, filters, balances, samples, gages, a wondrous panoply of instruments, allowed inquiring minds to develop the empirical base of observation upon which they built our stock of scientific understanding.

By working with digitally coded information, instrument designers are extending the power of perception greatly. The unmanned space-probes reporting on the solar system have perhaps been the most dramatic of these extensions, with wondrous photographs and other readings radioed back as masses of digital code. Not since the invention of the telescope has our ability to perceive the universe around us so leaped forward. But digital read-outs are all around us with the computer creeping into all sorts of mundane tools, enhancing our capacity to track and control their use. For many decades car instrumentation, for instance, was very stable, consisting of a few analog gages that indicated the car's speed and possibly the RPM's of the engine, while additionally giving key hints about the state of the car's fuel, coolant, engine oil, and electrical system. That's fast changing now with digital sensors in new and old places giving a much more exact picture of the car's condition of operation, with an onboard computer relating readings to one another -- "it's getting pretty close to empty" gives way to "range remaining fifteen miles." The computer will greatly extend the reach and accuracy of instrumentation as people apply it with increasing effects to small matters and large.

With the computer, people can externalize into their instruments more than their powers of perception. When Edison claimed that "genius is one percent inspiration and ninety-nine percent perspiration," he probably thought that the human capacity for both inspiration and perspiration were basically fixed, and by perspiration he had in mind the laborious calculations needed to test speculative insight, separating good from bad. Digital systems do not do away with the need for perspiration, but they extend what we can accomplish with a given amount of it. Most forms of calculation, correlation, combination, and connection that people can make, computers can help them make better. They can expand our abilities to sort, order, rank, and select. Even this process of externalizing powers of calculation is not entirely new historically, as one who has worked with a slide rule will realize, but it is being vastly increased. The consequences are likely to be very great.

Many people think that numeric calculation is the peculiar domain for computers, but their reach goes far beyond numbers. The computer can operate on anything that in some meaningful way can be represented in digital code through an organized data structure. And any operation that can be accurately described within the compass of binary logic -- AND, OR, NOT -- the computer can perform. Let us leave as moot whether people can, or should, or ever will, externalize into tools that one percent of their genius -- inspiration. They are externalizing in all sorts of ways that other ninety-nine percent, amplifying greatly their powers to calculate and control objects of their attention. Even if artificial intelligence, in the sense of the computer being an autonomous rational agent, is not soon coming to pass, if ever, AI, in the sense of amplified intelligence, is rapidly emerging all about us. We need to come to terms with its implications.

This, then, is the computer. It is the representation of our culture in digital code and the development of all the cultural possibilities that result. The computer makes cultural work easier to produce and reproduce, to preserve, to transmit, potentially accelerating intellectual attainment and opening cultural access in unprecedented ways. The computer greatly augments human powers of selection, memory, perception, and calculation, potentially amplifying the intelligence that each and all can bring to bear upon the panoply of questions that life puts to them. We turn to the implications of this computer for the activity of education.

Chapter Three - The Educator's Mission

Digitizing our culture will occasion significant historical change. It will not do so overnight, but in a matter of decades as we round one of history's majestic promontories. Should we go by adrift, blown this way, then that, in mindless disarray? Or should we sail confidently around the cape, adventuring hope and considering intent?

Only a catastrophe will stop us from rounding this historic point, driven by a powerful means of communication. This assertion does not propound a technological determinism, wrought as if technology were some suprahuman force, determining our lives apart from us. Technology is one human, all-too-human, means that people have always used to make their history. We, like they, will live with the consequences, and we need to take responsibility for how we shape our lives with our historic innovations, the computer among them. In saying that we are rounding an historic bend created by our inventing new communications technologies, we propound no determinism; we simply characterize the effect of human initiatives on the human destiny.

Thus Norbert Wiener, one of the key innovators in the development of automatic control systems, called his reflections on the social implications of cybernetics, The Human Use of Human Beings. One might think this title strange, if one thinks of the computer as something separate and apart from human beings. But it makes good sense, if one recognizes that the computer simply helps to enlarge our human abilities. The computer is extending human capacities to remember, to perceive, to think. It neither displaces these powers nor obviates our needs for them. Through technology, humanity augments itself, and humans are as responsible for their conduct with their powers augmented as they were without. As we extend our intellectual faculties with the computer, what human use of human beings should we fashion with them, particularly as educators?

The Reciprocity of Equity and Excellence

Equity and excellence: these aspirations have drawn Western culture into modernity, and for better and for worse they are pulling the other cultures of the world along. Both equity and excellence are many-sided aspirations and they have long stood in a creative tension with each other. Historically, educational effort has been one of the means for cultivating both equity and excellence in productive, potent ways.

Let us survey the historical significance of equity and excellence, the mission these qualities perform in life. In doing that, we do not intend to define them philosophically. We will neither argue normatively that here is the one correct conception of equity or excellence, nor pick analytically, exposing flaws in this or that version. Instead, we inquire why representatives of our tradition have taken equity and excellence seriously, seeing important matters to be at stake through them. What has been the use and disadvantage of equity and excellence in cultural experience?

Equity generates historical vigor. Where there is no equity, the favored become arrogant while the deprived become despairing. With an approximate equity, all persons and groups engage fully, from within, in the realization of their unique potentialities. Equity is to the polity what good conditioning is to the athlete.

Rarely has anyone argued that equity should produce universal sameness, entailing precise equality with everyone getting the same measure of goods, neither a jot more nor less, than anyone else. Human beings and their circumstances vary too much in real ways for mathematical identity to be the norm of equity. The norm of equity, however, cannot tolerate differences that are too extreme, so extreme that one person cannot recognize commonalty with another. Whether the cleavage be between rich or poor, townsfolk or peasant, minority or majority, domiciled or homeless, or any other distinguishing mark, it cannot be so great as to define separate orders of being that have no mutuality, one with the other. When that happens, equity disappears.

Equity involves respect for differences within a broad ambit of commonalty. This general principle links the main practical expressions of the drive to equity in our tradition -- equality before the law; the guarantee of minority rights; and maintenance of equal opportunity. Without equality before the law, commonalty breaks down and the community shatters between those who bear the burden of onerous laws and those who enjoy exemption. Without the guarantee of minority rights, respect for differences evaporates, suppressed at one or another difficult juncture by a tyrannous majority. Without efforts to preserve equal opportunity, separations in status and differences in condition build until neither haves nor have-nots can preserve a pretense to commonalty with their counterparts. Equity is unity in diversity, e pluribus unum.

What good arises historically when equity pertains? Were humans and their conditions all identical, equity would simply describe a condition, not an achievement, wrought for a purpose. But people all differ, and we can all mutually benefit from our differences when we arrange them well. Civilization, community, and polity all serve to enable people to arrange their differences in constructive ways: equity is the governing principle of these arrangements. Thus the fruits of equity seem somewhat paradoxical -- they arise, not from making everyone more alike, but in enabling people to share maximum benefit from their differences.

Plato began the Western discussion of justice by recognizing that human civilizations were complicated groupings of different people, each with different conditions, interests, and skills. Civilized people had a stake, he observed, in their not being all alike, but in their benefiting from their differences through a division of activity, with each person perfecting special interests and gifts. Justice was a peculiarly civilized problem, a problem of equity, one of harmonizing the fruitful differences among people so that the variety of capacities served the good of all. The virtue of each deserved nurture and respect. Equity allows each to realize unique potentials and to participate actively in the shared effort of civilization.

A society that does not maintain equity will include many who accommodate to misfortune through despair and passivity. They will not make the most of their possibilities and will drag as a weight on the resources of the whole. Others will experience their inequitable privilege as a dimension of their being, something not achieved but given in the apparent order of the world. They will fail to nurture acquired strengths, confusing such accomplishments with gifts of nature. Increasingly they will enjoy the forms of power, without its substance, lordly buffoons. Even between those extremes, where people would seem to enjoy a bracing modesty, they will deflect their energies in behaviors of avoidance and emulation, shunning the needy and aping empty privilege. Thus even the middle class can become at once anxious and over- reaching.

Equity improves the chances that a people will achieve a collective vigor in the face of history. Rarely does a single group by itself ensure the greatness of the whole. For the quality of life to flourish, a wide range of people must have a sweep of skills, each exerting effort, doing well what each does best. Equity makes it possible for each to feel that he can become somebody of worth and that he can do it best by respecting his condition, skills, and interests, making the most of what these are. Equity makes diversity beneficial. It leavens the energies of a people. Equity energizes: that is its historic value to the conduct of life.

We have been reflecting on what equity, as a condition, does for people in history. This question differs from the problem of how a people can achieve or maintain a condition of equity in their history. What food does for me is not the same as what I do to get food -- one has to do with nutrition, the other economics. How equity benefits civilization is not the same as how a civilization becomes equitable. Failure to note this distinction often confuses discussions of equity, especially as it relates to excellence.

Historically, where life is equitable, people will display more cultural vigor. People maintain equity through their history, however, by treating it as a difficult balance that they need to maintain and keep, a dynamic tension between commonalty and difference, unity and plurality, identity and multiplicity. Recognizing this tension, people can then use opportunities for change to move first toward one pole and then toward the other, whichever is deficient, continually channeling effort toward the side of the balance that seems then insufficient. Achieving and maintaining equity is thus like riding a bicycle -- the rider subtlety steers and sways against the direction of fall, turning away from a tumble, crossing the balance point, and then turning back the other way as the imbalance reverses. Should she lean exclusively to this side or to the other, the rider will flop to the ground. The rider keeps the bike upright, continually steering it away from the side to which it is falling, bringing it upright, then starting a fall in the other direction, all as a simple expression of her kinesthetic sense -- she acts and does not find it easy to be consciously articulate about riding a bike. So too, people maintain equity, moving back and forth between commonalty and difference, as a simple expression of their sense of justice, sometimes nurturing distinctions and sometimes leveling differences in ways that they sense to be fit even though they may find them hard to plan or explain.

As movement enables the rider to steer the bike against the direction of fall, so historical development allows people to maintain equity by swaying between commonalty and difference. In a static society, people cannot shift their direction between solidarity and variation, and an imbalance toward one or the other cannot be righted. Perceiving this link between social rigidity and the loss of equity, ancient Greek historians argued that a breakdown in equity caused stasis, the paralysis of a society riven by excessive differences. They had cause and effect reversed, and Machiavelli in his Discourses explained most clearly that the problem really worked the other way around: when dynamic development petered out, people became frozen in their oppositions, unable to shift against their fall. Then their differences inexorably widened, equity decayed, and the creative components of society turned to internal strife, one with the other, leaving the culture in a prolonged, irreversible decadence. In contrast, in a continually developing society, dynamic circumstances enable groups to change their direction of movement with respect to difference and commonalty, shifting from leveling to differentiating and then in time back to leveling and on, thus permitting the preservation of equity over time.

Expansion, change, dynamism: these enable people to sustain equity over time. One cannot balance the stationary bicycle. In the same way, a quiescent society, one that lacks historical movement, cannot maintain equity. Thus, looking at what equity does for people in history, we have observed that the condition of equity maintains the vigor of a society. But looking at what people must do in history to get and preserve equity, we find that their capacity to change, to develop, to move dynamically in history enables them to approximate and maintain equity over time by employing their sense of justice to shift between cultivating commonalty and then difference, difference and then commonalty, thus keeping the dynamic balance, riding the bicycle of time.

What drives this capacity to develop, to change? What pedals the historical bike? Here excellence enters the equations of history. Historic development flows from the ability to break through the molds of the moment. A person who excels at something penetrates beyond given levels of achievement. Historical dynamism arises from this drive to excel. Conservative excellence is an oxymoron, and its proponents confuse real excellence with conventional achievements. In actuality, equity is the much more conservative virtue, for it enables each, in a fit way, to contribute to the common enterprise. In contrast, excellence does not conserve; it forces change. To excel is to shatter molds, exceed norms, to better the existing standards. An ever flowing excellence preserves the dynamism, the historical movement, that permits people to maintain equity. Excellence drives change so that people can accentuate commonalty when differences begin to become extreme and they can nurture differences when commonalty begins to cloy and suffocate the spirit. Excellence, by breaking beyond the given, turns the wheels of change.

Many who write in praise of excellence attribute to it the fruits of equity. Excellence does not necessarily guarantee a high level of competence across all the walks that contribute to the common weal. General levels of competence are the work of equity: with equity, each person feels that she has a fair shake and will, therefore, live her life, integrally, to the hilt, proud and engaged. To attain a high level of general competence, each and all must exert themselves, and equity promotes such universal exertion. Historical change, however, does not come from diffused competence, but from localized, unexpected innovations that alter existing balances between groups and functions, unexpectedly forcing readjustments among all components of society. These innovations take place when someone, in one or another walk, comes to excel all expectations, to surpass existing norms and eclipse familiar patterns.

An historic flow of excellence keeps a civilization in dynamic development, allowing it to maintain equity over time. Thus we can say that the historical function of excellence is to be the historical source of the condition of equity. What, however, is the historical source of excellence? If excellence produces equity, what produces excellence? To a certain extent, excellence is an indelible expression of the human spirit, what Nietzsche called the will to power, an aspiration to find and fulfill one's possibilities. In this sense, excellence happens anywhere, often under the least propitious circumstances. Thus change has eventually, surprisingly, welled up throughout all societies, even the most static and regressive. Yet however inexorable, excellence as a driving dynamism has been more prevalent in some societies than in others and it is for this source of relative prevalence that we search.

With respect to the maintenance of equity, significant excellence can originate from any sector of society. In that sense, excellence is intrinsically egalitarian. What is important in excellence for keeping equity is not that excellence occur regularly at the leading edge, whatever that may be, but that it occur with sufficient dynamism that it forces readjustments among all the parts, allowing them to shift orientation, like the cyclist, between the poles of equity. Such excellence can sometimes occur in a society that arbitrarily channels all advantage to limited groups, but it does so very rarely as the indelible spirit rises up from within one or another dispossessed group. Thus redeeming religions arose from decadent cultures. But societies that provide all their participants with opportunities to develop, to generate a compelling excellence, will more continuously undergo the dynamic readjustment of their parts.

Increasingly in modern societies, people have been using the intrinsic egalitarianism of excellence to maximize the likelihood of its occurrence and to keep social relations in continual movement. Since excellence can occur unexpectedly in any and all walks of life, a society that approximates equity, and provides all walks with nurturing opportunities, will be the most dynamic, the one continually forced to undergo change and innovation. The frequency with which an energizing excellence wells up will be improved by ensuring that each and all have opportunities for self- development. Here is the wager of participatory polities: equity is the historical condition that increases the frequency that excellence will emerge in one or another sector, forcing realignment throughout the culture.

Excellence sustains equity; equity occasions excellence. Excellence drives historical development; equity spreads human competence. The two together foster progress, an improving quality of life for a growing number of persons. The great achievement of modernity -- roughly the half millennium from 1500 to 2000 -- has been to harness equity and excellence together and to use them to transform both the material and cultural conditions of life, extending unprecedented opportunities to a multitude of peoples.

During this period, technologies for the mechanical reproduction of information, particularly printing, greatly facilitated efforts to promote both equity and excellence. Printing expanded access to the defining documents of law and religion. It empowered vernacular cultures to address all the complexities of civilization and it evinced the creation of a community of scientific discourse. Printing altered numerous arenas of activity, giving people the opportunity to achieve unprecedented excellences in them. Printing also enhanced equity by nurturing both commonalty and diversity, helping to provide general access to cultural assets and to preserve the distinctive resources of numerous groups and specialists. Consciously and unconsciously, people made printing a powerful leaven in modern culture by discovering ways to use it as a means promoting both equity and excellence.

No less needs to be done with the computer as a system. We are rounding a bend of history that will express our culture in digital code. We should do so aware of the importance of equity and excellence for the enduring quality of historic life. During the rise of modernity, education has been a domain that helped to link equity and excellence constructively, making use of the pedagogical possibilities of print. The task before us now, as the era of print gives way to that of the computer, is to find ways to renew the pedagogical link between equity and excellence, which has been strained of late.

Educators have a mission to nurture our historic capacity for equity and excellence. To do that, they need to use advanced technologies to create an education that will be both integral and liberal, both meaningful relative to each person and worthy of each person's autonomy.

Education, Liberal and Integral

It is one thing to say that education should promote equity and excellence. It is another to explain what kind of education can best do that. Links between educational activities and their results, both biographical and historical, are not direct. People believe that the extent and quality of education makes a difference in the experience of individuals and groups, but the results unfold slowly over time and many other contingencies affect the outcome.

Most tests of educational outcomes cravenly duck this difficulty. Evaluators assume that all results empirically evident at the conclusion of an educational activity will endure, relatively unchanged, for as long as they may be significant. Thus they measure the quality of education by the grades a person earned in a sequence of courses and they estimate the quality of schools, teachers, and programs by measuring how well children perform under their influence at one or another instant of time. It is a testament to our tolerance for absurdity that the educational research establishment allows such a methodology to stand.

Think of investment theories. With respect to education, researchers and the public obsessively look only at the rate of current return. Which method, they ask, yields the highest immediate gain? Economists long ago realized that this was a poor way to ascertain the value of an investment, for every investment has a useful life, which may be long or short, and a pattern of payoff across that life, which will vary, instance to instance. By measuring only the immediate current return, investment in growth industries would make little sense at their start, for at the start growth industries often lose money and usually require plowing back whatever profit they generate into development and expansion. Often the time to invest in growth industries is when they have negative current returns. In general, if people judged only by current returns, practices of deferred gratification would seem merely masochistic, yet these have been among the historically most productive economic strategies. Like economic investments, the benefits of education accrue over long periods and they accumulate in many forms. Our educational measures provide very weak resources for investigating these cumulative benefits and educators consequently have trouble making good sense of the relative value of the various means they might adopt.

If the computer as a system has fundamental significance in education, it will be as a long-term transformative agent. Experimental measures of how effective one technique is relative to another rarely measure long-term secular effects, showing how a systemic innovation, operating from kindergarten through graduate school, performs, across the full span of people's lives, relative to other system options. In education we have not yet invented the techniques of integration for calculating the full values of the whole education, leaving claims of measured worth partial and deceptive. Hence, little will be gained by culling the literature to show that a selected method, used in this subject through that grade, will accelerate performance by some fractional current return. We should legitimate experiments in a different way.

Let us try a different method; let us attend to intuited preferences, especially to those that recur frequently in different times and places, trying to reason out why those intuitions may have a vital truth to them. Over and over again, people in many times and many settings have had strong, intuited preferences for and against particular types of education. Neither they nor we can rigorously measure out quantitative grounds for these preferences, taking the full span of education from infancy through maturity into account, but we can thoughtfully understand them and perhaps see how they connect to the imperatives of equity and excellence. Such reasoning may help us understand how to use digital technologies as historically constructive agents in education. Here we will concentrate on two such recurrently intuited preferences, a persistent quest for an integral education and for a liberal education, which we will see, as our reflections unfold, link pedagogically to the more general aspirations of equity and excellence.

Commentators often resort to the term "liberal" in discussing education. They rarely agree precisely on what it means. I will return to the topic and give a version of it. But first, let us consider the other recurring preference, that for an integral education. Commentators rarely use the term "integral" in discussing education. Yet they almost always agree about the matters that we can describe with this term. An integral education is one that the student integrates and makes her own. Educators analyze the functions that lead to an integral education when they study the processes of assimilation and stress the importance of intellectual synthesis. Likewise, they have often decried education that fails to be integral, objecting over and over to rote learning, empty mimicry, and taking on airs. If the term is a bit novel, the phenomenon is not -- it simply has not been definitively named in educational discourse.

Education should be integral, it should consist of things that a student integrates into a set of skills, understandings, preferences, and beliefs that comprise a whole, one that integrally characterizes the person. A person who has achieved an integral education would be likely to have what psychologists once called "an integrated personality," and would be, in an even more traditional terminology, "a person of integrity." Integral education need not lead to bland sameness in all; rather, as we will see, it should take into account the differences that characterize each. Cultures are collective human works of such complexity that no person can integrate into his character all that is of value in one of them. Were a culture so simple, or the human character so all encompassing, history would freeze in a repetitive classicism, which is probably why so many primitive cultures persist unchanging. In a single, complex, culture, many, many different integral educations are possible and desirable.

People do not easily achieve an integral education. The world of education has many stock nincompoops -- pedants, bores, pettifoggers, humbugs, fakers, dreamers, incompetents, sticklers, marionettes, drones, bombasts, drudges, and charlatans. All exhibit a failure to integrate acquirements fully. In a more positive vein, the great studies of education in our tradition have put the problem of integral education central. Plato's Republic, turns on the question of how the person can integrate appetite, emotions, and reason in a harmonious unity in which each part, keeping to its proper business, contributes constructively in coping with the claims of experience. Rousseau's Emile, turns on the issue of how the wise educator can hearken to the unfolding readiness of the maturing child so that her development is neither forced nor stunted, keeping instead to a regimen of challenges that strengthen her as she rises to each. Dewey's Democracy and Education turns on the problem of situating the child's growth in his reflective experience, nurturing and sustaining it, from the world of play outwards into that of science, work, social bonding, and politics. Throughout these, and many other works of our educational tradition, the pedagogical problem centers on the importance of integrating the particulars of education into an integral whole for the person and the group.

How does a person integrate cultural acquirements into his character? Consider some hypotheses responsive to this question, a question that is far too complicated ever to receive a conclusive answer. The generalizations that follow here have their roots, not primarily in psychology, but in history and other cultural studies, along with simple introspective reflection. We should entertain them, not as claims to achieved knowledge, but as design heuristics that may enable us to create more effective modes of practice. Too often, educational researchers adopt methods that exemplify the old saw, "penny wise, pound foolish." Let us reach, as widely as we can, for knowledge tested in the crucible of controlled observation. But when, owing to the complexity of the activities at issue, we cannot subject the full spectrum of relevant variables to sound experimental study, let us not truncate our thinking about them to deal only with those few variables that we can grasp through controlled observation. Where the phenomena are many-sided, as in understanding how a person integrates cultural acquirements, we should turn to philosophy, anthropology, history, literature, to all the human studies, to advance our reflections.

In integrating learning, it does not suffice to learn to recognize something or even to repeat it on cue, or to know a lot about it. A person who thoroughly assimilates a language may know far less about it than someone who has been taught it extensively without integrating it into his living or his work. An integral education challenges a student with things that are new to him, but it also allows him to select, to incorporate, to synthesize the new into what he knows, thinks, and believes. Sometimes, something new will not simply integrate with what came before, but will force him to reintegrate many of his ideas, and he will call that a transformative educational experience. Traditionally, formative education, which accentuated the ardor of thoroughly assimilating one's learning into one's life and work, often called for long apprenticeships capped with production of a difficult, unexpected masterwork.

An integral education will usually be a student-centered, active education. Teachers cannot integrate material for their students. This problem is quite evident for anyone who tries teaching skills that depend on a person's kinesthetic senses -- just about any sport that turns on one's sense of balance and coordination. Take, for instance, water-skiing. You can explain to someone what to do over and over. He won't get it until he gets in the water and feels the pull of the boat, the resistance of the water on his skis, and then, quickly or laboriously as the case may be, he gets the knack of letting complex forces intersect through his legs, arms, and torso. At that point he has integrated instruction and experience, using his kinesthetic senses to get up on the skis, and a whole new discourse can start between teacher and student, a discourse based on a shared understanding of the essential experience. The same holds for cycling, dance, gymnastics, diving, the use of tools: "let me show you" can at best inspire the student to trials in which he gets the feel for it himself and then a new exchange can begin between two people, who both know how to do it, in which they exchange the fruits of their complementary experiences.

As learning to manage one's body in complex ways requires that the student use her kinesthetic senses to integrate precept and example into her set of abilities, so too does integrating intellectual and emotional acquirements. Here the essential resource is the sense of judgment. Do not understand by "the sense of judgment" a quasi legal process of applying rules to instances, handing down a judgment about how a rule applies to a case. Rather the sense of judgment is a philosophic term for the process by which a person forms likes and dislikes, commitments, and rejections, in the full flux of experience. The sense of judgment generates selections. It is a biological, characterological, esthetic sensibility, and a teacher must appeal to a student's sense of judgment -- her sense of the interlocked importance and significance of things in the world she experiences that she uses to make choices, to allocate attention, to discern differences, to perceive possibilities, to respect limits, to sense dangers, to define aspirations, to obey precepts, to form intentions, to act for herself in her world. An educational system that does not effectively engage and make use of the sense of judgment that its students possess will be futile and dysfunctional.

Educators do not find it easy, however, to work with and through their students' sense of judgment. The system often functions as if students neither can nor should form likes and aversions according to their inner light, whatever that may be. "Eppur si muove. But still it moves," Galileo muttered, and so they do. Hence, the ineluctable working of each student's judgment, affirming this and rejecting that, makes it necessary that the design of formal education pay careful attention to the diversity of cultural and social conditions. Anyone can have transformative experiences, for better and for worse, and with only a few constructive (however painful) transformative encounters, the anonymous child of poverty and cultural marginality can rise to great achievements. But such metamorphoses will not occur without recognizing the child's sense of judgment as it stands, from the beginning. Hence, the refined preferences of bourgeois civility cannot be the presumed sense of judgment in an education for someone for whom street-smarts are a condition of survival. Instead, the starting points for integral education need to be numerous, diverse, and many-sided.

What are the forms of integration in education? To develop a sense of their range, reflect briefly on three ideal-type constructs that we can generate intellectually to help organize the wealth of experiential particulars -- combinatorial integration, self-reflective integration, and transformative integration. The first, integrating things by combining them together, seems to start early as the child draws connections wonderingly between different elements of experience. Combinatorial integration is relatively uncritical. It motivates all those childish questions -- what? how? why? where? when? The integration happens by a kind of passive proximity -- things need to stand just beyond the perimeter of the person's understanding so that he can encounter them and spontaneously make a connection between what he knows and these new matters. If he simply stays within his web of existing connections, no new combinations form, and if something is too distant from his current stock of integrated information and ideas, he will just let it pass without forming a lasting anchor in his realm of attention. Although it is most common in childhood, combinatorial integration continues through life and it is the normal way people incorporate new impressions and form new skills. Daily attention to the news probably has the function of exercising and keeping current a person's combinatorial integration of experience.

Self-reflective integration involves bringing to consciousness the unifying interests and capacities that constitute an assertion of unique personhood. Often, this form of integration seems to start in adolescence and to carry through early adulthood with the formation of a conscious vocation. For self-reflective integration to occur, a person needs a sense of multiple options. She exercises a projective imagination, seeing different possibilities unfolding in the foreseeable future. She discovers that her interests are many- sided and cannot all be reconciled together by simple combinatorial judgments. Choice becomes necessary, and with it arises the need for criteria and principles, a conscious sense of self, goals, purposes, tastes, and values. She must form these for herself and in modern Western cultures, at any rate, often she rails at the bland assumption of her elders that of course she will simply take on all the norms and expectations that they model for her. Yet forced into self-reliance in this self-reflective integration, she feels that the stakes are high -- while rebelling against presumptive models, she looks about for inspiration and encouragement, and step-by-step she forms her controlling sense of self.

Transformative integration shatters a person's established sense of self and recombines the parts in a new combination and purposeful orientation. Such a reintegration can occur at any time of life, usually through powerful experiences not under the person's control -- a trauma, disease, or upheaval in circumstances. Some significant challenge upsets a person's existing order of ideas, skills, and convictions, and he must reintegrate them in order to cope with the new circumstances. Sometimes in the course of formal education, one encounters a new perspective on things or new ideas or data that undercut the existing integration of a subject, forcing one to rethink it all. Increasingly, as the normal life span lengthens and people seek to maintain a sense of vital engagement with their circumstances, they subject themselves to transformative challenges, consciously through career changes and unconsciously through mid-life crises.

An integral education will help the person use her judgment to mobilize the fullest range of knowledge and skills in defining and pursuing the vital itinerary of her life. Insofar as her education is not integral, it will consist of acquirements of no vital import for her, of skills that will decay unused, of things learned but soon forgotten, of masks and routines performed with hidden resentment to please the powers-that-be. Through an integral education, a student takes responsibility for being whom she is, for both those things she recognizes as fruits of her conscious will and for those things she knows to have been accidents, whether negative or positive, that befell her arbitrarily, yet befell her, and not someone else, some other onto whom she can pass responsibility.

Integral education involves not a sovereign, all-powerful self, but the ever-varied particularities of personhood. As we shall see, each person's achieving an integral education is a key to promoting equity in our culture, But for now, simply let Michel de Montaigne sum up the ideal of integration in education -- "Bees pillage the flowers here and there, but they then make honey of them which is all their own; it is no longer thyme and marjoram; so the fragments borrowed from others [the student] will transform and blend together to make a work that shall be absolutely his own; that is to say, his judgment. His education, labor, and study aim only at forming that."

As Montaigne perceived, through an integral education a student forms her judgment. In this sense, an integral education is closely allied to that other recurrent educational preference, namely for a liberal education. Let us reflect on the preference for a liberal education and then return to see how integral education and liberal education together help nurture equity and excellence in historical experience.

One can find numerous different descriptions of liberal education. In part, this multiplicity of visions has arisen because commentators treat the term "liberal," not as an adjective, but as part of the noun phrase, "a liberal education." They busily describe the distinctive features of a liberal education and they of course differ about what these are. Let us ask instead, why did people start qualifying education with the adjective "liberal?" They started using this adjective because it meant "appropriate for a free person." They did not mean by this that a certain kind of education would take slavish youths and magically make them free. The autonomy of the person was not the result of the education; the autonomy was the condition occasioning it. Some people were free, as distinct from dependent, and free persons would find a certain type of education particularly appropriate for themselves, which came to be called a liberal education -- an education worthy of the autonomous, self-directing, responsible person.

No studies mysteriously made people free; no subject had a liberating potency. The autonomy of the student, his moral freedom and responsibility, was not the consequence but the condition of a liberal education. Only on recognizing the student's inalienable autonomy did the choice of subjects traditionally represented by the liberal arts make sense. An unfree person lived and worked, bound by a determining status that laid down what skills and knowledge the person would need in order to function effectively within his allotted station. For the unfree, efficient education would impart those predetermined acquirements and nothing else. For the free person, the self-determining person, the problem of education was more complicated. What skills and knowledge the free person would need in the course of his autonomous conduct in the community could not be fully predetermined. Hence, an education worthy of a free person was one that would enable him to learn whatever skills and knowledge he needed as he conducted himself in open-ended self- governance. In order to do that without incurring a crucial dependence, exactly when autonomy was at stake, he needed to be able to learn his ever-changing skills and knowledge without dependence on paternalistic teachers and other authorities. Consequently the liberal arts were those disciplines the mastery of which would enable the free person to grasp any further concept or capacity as the need arose without dependence on teachers.

Note the phrasing, "without dependence on teachers." This stricture does not suggest that the free person will be without teachers. Quite the contrary, the free person will be autonomous with respect to them, taking responsibility for attending to this one and ignoring that one, able to judge the worth of their teaching for herself. What does a youth, aware of her autonomy, want as preparation? She sees life as a continual development throughout which she will always be responsible to herself and others for certain particulars. Owing to these responsibilities, she seeks competence; but having a keen sense of her ever-changing possibilities, she cannot say honestly exactly what competencies she will desire as she unfolds her life, and she is loath to let her pursuit of competence hamper her prospective development. Consequently, she seeks an open preparation that will enable her, in the all-important school of life, to move forward independently into whatever matter she feels drawn. Hence, neither an introduction to the great books nor the beginning of a specialty, the liberal studies were simply a rigorous discipline in the intellectual tools with which one could gain access to any particular matter. Such access might involve intense engagement with teachers -- be they persons, books, or situations. Having had an education worthy of a free person, she would proceed through those engagements without becoming dependent upon them.

In ancient times this discipline in the tools of study came through grammar, rhetoric, logic, arithmetic, geometry, astronomy, and music. But these subjects were not the crux, making the education in them liberal. They empowered people to conduct themselves later in life in ways befitting their freedom. Hence, ancient commentators like Seneca derided people who took pride in being occupied with the liberal studies; he held that one should work instead to be done with them, for no good came of them themselves; rather, they served simply as a preparation for the truly serious matter of self-formation. Can someone, after a suitable preparatory discipline and engagement, acquire new knowledge, skills, and understandings on their own without dependence on teachers and formal instruction? If one can answer in the affirmative, that person has a liberal education, an education worthy of an autonomous person, one who can proceed to acquire needed knowledge without reliance on others.

With the liberal assumption of the student's autonomy, the teacher accepted an important but highly circumscribed function: the self-effacing work of making himself unnecessary. Most pre- modern pedagogy is incomprehensible without realizing that its aim was not to make the teacher more effective, but to make him progressively less important. Traditionally, teachers had the self abnegating responsibility to make their assistance unnecessary by helping students build up their capacities to learn on their own. This is a goal common to most professions. The doctor who healed in such a way that he promoted the permanent dependency of his patient on his prescriptions would be called a pusher, not a physician. The healing arts aim to bring the patient to full strength and vigor, where she is no longer dependent on medical care. So too, the teacher should build up a student's capacity to learn on her own, independent of the teacher's care.

Traditionally, this effort to educate to independence was a controlling goal of educational practice. Formal pedagogy was to help the student arrive as quickly as possible at a point at which he no longer needed instruction in order to continue developing apace. For instance, the medieval scholastic, John of Salisbury, observed, when asked why some arts were called liberal, that "those to whom the system of the Trivium have unveiled the significance of all words, or the rules of the Quadrivium have unveiled the secrets of nature, do not need the help of a teacher in order to understand the meaning of books and to find the solutions of questions." This same desire to end one's dependence on one's teachers was implicit in the way the Renaissance educator, Batista Guarino, recommended his course of studies: "a master who should carry his scholars through the curriculum which I have now laid down may have confidence that he has given them a training which will enable them, not only to carry forward their own reading without assistance, but also to act efficiently as teachers in their turn."

Consider again the question of equity and excellence. We can hypothesize that a liberal education, the capacity to acquire further mastery independently, helps a person to achieve excellence. To excel is to transcend the limits of attained achievement, to pass precisely into those regions where teachers cannot lead. Excellence is a free assertion, a gratuitous quality, something achieved but not mechanistically caused. An education worthy of free persons enables a person to excel, not because it makes her excellent, but because it helps her make herself excel. Educators cannot guarantee that someone in their tutelage will come to excel in a particular walk of life. Such eventualities are beyond the educator's reach and depend on the student's ability to sustain her drive later into the realm of unprecedented achievement. What the educator can do is help the student develop abilities to learn self- sufficiently whatever she later feels she needs. Having become able to learn what she will, without dependence on help from others, the person pursuing excellence can better navigate the realm where she is setting new standards. As an education that enables a person to learn ever more without dependence on teachers and authorities, a liberal education supports people in their drive to excel.

In a similar way, we can hypothesize that an integral education supports the quest for equity. Equity in education entails in large part, that each person, despite differing from others, should attain an integral education. The problem with equity is to respect differences while maintaining commonalty. This problem of equity is most acute, not with respect to "other people," but with respect to "each person." How can one, regardless of one's race, religion, creed, condition, and country of origin, come to respect one's own identifying differences while affirming one's solidarity with all others, recognizing each in his turn as equally unique yet essential to the whole? Through an integral education, a person integrates his acquirements, taking possession of them as his defining qualities within the whole community. If all can achieve an integral education, the grounds of equity will be secure.

Unfortunately, the balance between difference and commonalty is hard to keep in education, particularly when we attend to the education that each person experiences. Education too often suppresses differences and promotes a superficial sameness, something different from genuine commonalty and something that impedes the attainment of an integral education. Diversity is not a sign that education has faltered, however; diversity is the cultural genius of the human species. If people were all exactly alike, educators could offer the same education to all, expecting each to integrate it equally well. But people are different. If they get identical educations, some will find it much more difficult to integrate what is in them. What "each person" learns at that point, when she encounters the common pedagogical program from the specific ground of her unique cultural heritage, can strain equity severely. Then the common program savagely insinuates its biases: "they are advantaged and you are impaired; don't ever forget it." Recognition of such adversity may goad a few to redouble their efforts, but it prompts many to withdraw.

Educators have long understood this problem and have long thought it important to individualize instruction so that different students all have relatively equal opportunities to achieve an integral education. To do so is not easy. Consider for instance the problem of teaching reading in an inner city barrio. Many children will have difficulty integrating this skill into their daily lives. Those around them will not spend much time reading, and reading materials will not be casually at hand. If they are, they may be in a language different from that of the school. Thus it will be more difficult for such a child to integrate reading skills into his sense of what is important. And the difficulty then gets doubled -- the content of formal instruction often then turns out to have less objective value for the child of the barrio than it might for someone else, or it may powerfully appear to be of less objective worth. Under such circumstances, a student will find it both harder to integrate the skill into his set of acquirements and then harder to integrate that set of acquirements into a sustained set of accomplishments. This is not to say that reading is unimportant for the children of the barrio; rather it is to observe that equitable access to integral education is not easily attained.

If the education of each is integral, consisting of challenges that push each to realize his full potentials, delivered in such a way that he has been able to integrate all the resulting acquirements into a stable, unified, self-directing sense of purpose, then equity will have been pedagogically furthered. If that education is also liberal, culminating in a set of capacities that enable each to learn thereafter whatever skills and ideas he may need, without reliance of the fortuitous availability of suitable teachers, then the conditions for excellence will have been educationally maximized. Can the computer as a system extend the opportunity of each person to acquire an education that is both integral and liberal? If we can answer this question in the affirmative, we can be confident that the digitization of our culture will enhance the educator's mission.

Chapter Four - The Span of Pedagogical Possibility

"No one yet had printed books, the preceptor alone had a printed Terence. What one read must first be dictated, then defined, then construed, and then only could he explain it...." Thus a Swiss educational reformer, Thomas Platter, recalled his experience in a school around 1515. Through a long life as printed books became common resources for preceptors and pupils, Platter's own educational experience showed how the spans of pedagogical possibility can change.

Platter's family were peasants from a small village, high in the Swiss Alps. His father died when Thomas was two. At five, Thomas started the school of life, herding goats in the mountains, and by eight, accidents had nearly killed him several times. By luck and quirk, his guardians decided that he would do better to take a long shot and try to gain learning and become a priest.

Essentially two ways then led to this goal, one religious and the other secular, and Thomas tried both. For the religious, he had a brief, disastrous stint at a nearby song-school, a place where a priest trained boys to sing the liturgy and chant the mass, but not to read or to write. If this went well, it might have led to a cathedral or monastic school, but in Thomas's case the song-school went badly -- the priest had frequent bouts of drunken rage, and suffering from child abuse, Thomas withdrew. Then his elders tried the secular route, sending Thomas on the road. They put him, about nine, in the service of a distant cousin, a youth of about sixteen, who was a wandering scholar, a bacchante, going from town to town in middle Europe in search of the elements of learning. As was the custom, Thomas supported the pair, begging for their bed and board, sometimes stealing, rarely studying. After nine years tramping hither and yon across middle Europe, stopping at many schools for short or long, depending on the quality of the begging, Thomas finally settled in Zurich, an unkempt eighteen-year-old, still seeking the rudiments of Latin.

Such was the typical saga of a poor student prior to the era of the printed textbook. The whole system was part of a barter economy: if the schools were good, word got around and too many students would gather, making the begging miserable, and if the schools were bad there would be few students and good begging, leaving learning problematic. When it went well, the idea was to learn how, using Latin, to transcribe spoken text accurately in writing. The basic pedagogy, elementary and advanced, worked like dictation exercises in a foreign language sometimes still do: a teacher would read a passage aloud and students would try to write it on wax tablets and then the teacher or assistants would correct the transcriptions with each student, explaining their errors of grammar, spelling, and the like. Advanced instruction consisted largely of public readings of important texts, which students who had become skilled in transcription could take down for further study, provided they had the means to buy ink and parchment. Thomas Platter did not make it to this level by these means, however.

Until his return to Zurich, Thomas had participated in the pre- modern world of education. Prior to about 1500, educators had to assume that students did not possess a text pertaining to the subject at hand. Since mastery of key texts by priests and scribes was nevertheless culturally important, the basic technical rationale of pre-modern schooling was to find a way to enable a student to make the texts he needed. Thus much of instruction, regardless of level, consisted in dictation, reading a text aloud so that students could write it down, making at least a rough copy of it for themselves. The task of the teacher was to correct the student's efforts at transcription, ensuring that the sense said had been accurately written. Only very late in a student's educational experience did attention turn to questions of the meaning of the material.

In pre-modern education, where the student did not possess the text, learning to read and write, especially in the languages of scholarship, was a big hurdle. How do you enable someone who neither reads nor writes to make the elementary texts and grammars with which he can then learn to read and write? And all this had to be done, not in the mother tongue, but in Latin, the special language of religion and scholarship. Thomas never solved that problem. In Zurich, just on the eve of the Protestant reformation, Thomas encountered a teacher who simply provided him with printed copies of the texts. The problem of education ceased to be one of learning to write down the spoken text and became one of learning to read the printed text.

Thomas's studies then prospered, although they carried him naturally into the Protestant camp and to his family's consternation he took vows of marriage, not the priesthood. He moved to Basel and became a skilled artisan, printer, real estate entrepreneur, and finally a respected, influential schoolmaster. His school was not for wandering scholars, but for the children of the town burghers, securely part of a growing money economy. He negotiated with the city fathers a substantial salary for himself and decent pay for his assistants, one for each class. His students learned from printed textbooks and they moved, in age cohorts, through a graded curriculum. It began by inculcating the skills of reading good Latin, and it ended with the substantive interpretation of significant Latin works and study of elementary Greek. It was a typical, early- modern Gymnasium, designed to take advantage of printed texts.

The School and the Printed Book Platter's life spanned a period of great educational innovation. He and other reformers worked out the basic technology of modern schooling. The most influential among them -- Erasmus, Luther, Melancthon, Sir Thomas Elyot, Comenius, and more -- were great textbook pioneers and prophets of the importance of reflective reading as a source of knowledge and conviction. Others, scarcely less influential -- Loyola, Sturm, Ramus, Ascham, Mulcaster, Rathke, and many more -- worked out the design of the print-based school, developing strategies of competitive motivation, age grouping correlated to curricular sequence, manageable divisions of subject matter, and standards for the training and selection of teachers. Between 1500 and 1650, the key features in the technology of modern schooling were invented and implemented.

Since the start of this technology of schooling, it has developed into an extraordinarily successful system. Contemplate the very big picture -- the world-wide system of schooling that now exists. In the 1985-86 school year, over half a billion children, world-wide, attended primary schools, over a quarter billion went to secondary schools, and nearly sixty million pursued higher education. Humanity spent more than three-quarters of a trillion dollars that year to school its young, an annual amount that has risen to over a trillion by the inertia of inflation alone. Nearly all that effort conforms broadly to the plan of Platter and his peers.

At the few outermost reaches of this system, we would find it hard to recognize the schools as such, textbooks being very scarce and the principle of age-grouping hard to apply. But throughout almost all its world-wide scope, across great differences of national culture, wealth, and political ideology, the schools employ a remarkably common set of fundamental strategies. School systems group children primarily by age, secondarily by ability; they divide the curriculum into subjects, package these into annual installments, and map them onto the sequence of grades, a kind of educational ladder that children climb up as they mature from 5 or 6 to 17 or 18. The whole effort inducts the young, to varying degrees of mastery, into the resources of the printed culture. All of us have been through it.

People like Platter invented this system in the sixteenth century. His childhood education would be very strange to most anyone brought up in the twentieth century. But his school in Basel would be, discounting the choice of subjects, quite familiar. The educational technology of schooling derived from the sixteenth century. In this sense, the strategies of schooling are one of the most mature, fully developed of modern institutions, having evolved over a longer period than the other institutions of industrial democracy. To some commentators, the system of schooling superficially seems newer than it is, for the print-based schools have proliferated remarkably during the last hundred years. But significant changes in the design of these schools did not cause their recent proliferation. Transformations in the social context did, enabling societies to implement the visions of universal, compulsory schooling originated by sixteenth century reformers. Let us reflect briefly on these recent developments so that we can see clearly how old the established technology of schooling is.

Although the print-based schools developed in the sixteenth century, powerful limitations restricted the spread of them until the approach of the twentieth. From the start, these schools were a bourgeois institution, in the original sense of the term -- inhabiting the towns, the burgs. Early-modern schools like Platter's served primarily the children of the towns, and secondarily the children of the elites, in surrogate towns, in the form of boarding institutions. From roughly 1500 to 1850, two limitations effectively restricted the school to the towns, and those limitations both changed significantly in the late nineteenth century, making the recent spread of schools to all segments of the population in almost all parts of the world both possible and necessary.

First, the demographic profile of the over-all population in Western societies, and elsewhere even now, limited the spread of schools. Traditionally, populations had large numbers of children and relatively few adults, a demographic condition that put a premium on apprenticeship and other education strategies that made children economically productive at very early ages. In order to extend schooling to all, not only would children have to stay out of the work force, weakening the productive capacity, but so too, a very large percentage of the adults would need to withdraw from primary production to become teachers. If, for every hundred people, fifty are children and fifty are adults, recruiting sufficient teachers to educate all through schools would be a greater burden on primary production that it would be were there only twenty children and eighty adults. Until recently, only the bourgeois groups in towns could afford and profit from the systematic use of schooling, for they early on developed the demographic strategy of limiting family size, keeping the number of adults relative to the number of children high. The industrial revolution generalized middle class urban demographics and made their schools a more feasible institution for all.

Second, part and parcel with the demographic changes, during the past hundred years transportation changes greatly widened feasible access to the schools. The general movement of population from rural to urban areas helped provide concentrations of a sufficiently large number of families in a small enough area to support nearby schools, but areas of relatively sparse population density remain and here good transportation has been essential to make schooling effectively available. Even outside of rural areas, as many towns grew into cities and many villages into towns, children needed transportation to and from schools. As a result, mass transit, the private car, and school bus systems have had more to do, technologically, with the recent spread of schooling than innovation in pedagogical design or classroom practice. The key pedagogical innovations, the basic instructional design of the modern school, derived from the sixteenth century as educators realized that their students would be able to work from a printed text, whatever the subject, whatever the level.

Printing gave rise to the technical strategy employed in modern schools: to use inexpensive printed texts as effectively as possible as a foundation for educational efforts, redefining the task of education. Formerly the task was to prepare scribes to write text accurately as they heard it spoken or read aloud. In modern schools, the task was to enable a wider group to acquire knowledge and skill by reading printed texts on a wide range of subjects. This task defines the technical strategy of modern schools, which have developed and matured over the past five hundred years, as educators have used the printing press, with the textbook performing a key function in the operation of the whole. The main features of the world-wide system of schooling arise from the way printed materials have determined the educational provisions designed to employ them.

to grasp this point, we might more fully trace out historically the way printing conditioned the invention of the modern school. Instead, for the sake of brevity, consider simply, as a thought experiment, how the physical attributes of books necessarily influence the way educators organize schools, particularly where the controlling intention will be to have students master broad substantive components of the culture. Think simply of books as objects that have a physical reality in contexts of use. It takes a year or so for an adept author to compose a book of ordinary scale and several periods of sustained concentration for a proficient reader to absorb it. Novice readers will need help in absorbing the books they encounter and the function of the print-based school will be to provide students with books and to help them master the printed contents. Certain controlling limits and determinations immediately begin to arise.

Roughly speaking, a competent, disciplined youth, age say of fourteen, can master the contents of five densely printed books, each say 750 pages, eight by ten inches, weighing three to four pounds, by concentrating on them for the better part of the day over the better part of a year, with effective help from others to clarify difficulties and to maintain the regimen. Fifteen to twenty pounds of books is a heavy load for this student, literally and figuratively. To expect a fourteen year-old to handle a heavier load would be unrealistic and for younger students the load would of necessity be lighter. Let us exempt the first five grades from our calculations, for the problem there is less learning from the printed culture than getting ready to do so. Assume that starting at age eleven students can work with fifteen pounds of books per year, five substantial volumes, doing so until they graduate seven years later. Under these assumptions, the intellectual content of schooling would need to fit into about 120 pounds of books, or roughly thirty-five volumes.

These material conditions bring many more characteristics and limitations with them. We have implicitly determined a sequential progression year by year, with the volumes for the child of eleven being set aside in favor of new ones when the child becomes twelve. But mastering all thirty-five volumes will take place over seven years. Can that be one straight march down the shelf of books or does some redundancy need to be included in the volumes? As there have to be gradations in weight, so there have to be gradations in difficulty and some cycling over the years through the full scope of studies will need to occur. Consequently, the scope of the material included in the set of volumes needs to be deflated by a redundancy factor. I do not know precisely what this factor typically is, but guessing low I would put it at one- seventh, meaning that our thirty-five volumes really contain only thirty volumes of discrete material.

Should a student devote herself to one volume only during any particular day, making as much headway in it as she can, or should she work during the day from several volumes, each in turn, for an allotted period? Quite early in the development of schooling, common sense or experience definitively answered: during the day the student should attend successively to several different texts. But that raises the question of how the contents of these several volumes should be organized. What separates one volume from another? This question leads to ever increasing divisions of intellectual culture into distinct subject matters. Periods and days are the material realities of school time -- subjects and lessons are the induced units for presenting the culture through print within the constraints of those divisions of time.

Should students work in unison, each fitting the same lesson into the same time, or should they work along divergent paths -- Julia doing her Latin volume while Henri does his algebra and Simon his geography? Were the latter course taken, the teacher would be continually juggling back and forth from one volume to another, workable perhaps with three tutees, but not a room of twenty-five pupils. Educators quickly developed the practice of having groups of students work in unison, all from the same volume. Recitation from the text entailed grouping students to work, not only from the same text, but also at roughly the same pace, which meant getting students together according to similarities of chronological and intellectual development. When people find themselves together, each doing the same task at the same time as the others nearby, comparisons of each to the others come naturally, and with that a kind of competition to perform the prescribed duties spontaneously arises, and policy quickly capitalizes on it. Such comparative performances become the natural measures of achievement, rather than the teacher noticing how well Julia, setting her Latin aside for a moment, could help Henri get through the difficulties he encounters with his algebra.

Should the thirty volumes that are roughly the maximum that any student can master through the print-based school be the same thirty volumes for all, or should each master a unique selection of thirty volumes? For a variety of reasons the system tends to have all students study the same set of materials. In part, economies of scale in publishing favor this solution and it greatly simplifies the logistics of the school. In part, it results from the decision to have all the students in a classroom working largely in unison. It helps to make units of pedagogical time and effort interchangeable from one class to another and from one school to another. The practice leads to important cultural distortions, however. It amplifies the cultural salience of the things included in the volumes that all will study, and it puts the many things left out in a kind of cultural deficit.

Rather than continue this thought experiment to show in more and more detail how the material constraints of printed books shape the features of the world-wide system of schooling, let us summarize the essential point. Many critics complain that textbooks are too central in the process of schooling. Their complaints miss the mark. Schools as they exist were invented to take advantage of the possibility, arising with the spread of printing, that both students and teachers could always have an appropriate text for any educational encounter. The centrality of the text determines the entire design of the system. Schools designed to use printed texts systematically have been an immensely productive development in the history of education. These achievements have been justly celebrated. Let us, without denigrating those achievements, try to fathom further the limiting constraints on educational achievement inherent in this print-based system.

Implementation Constraints of Print

Big-time basketball players must stoop to go through most doors. Left-handed people find it hard to crank can openers or pencil sharpeners, which usually convenience right-handed people. The width and number of the road lanes and the average size of cars define thresholds for traffic density above which drivers will slow up significantly, causing delays and jams. All such problems exemplify implementation constraints, limitations of effectiveness and the ease of use that arise from choices that must be made in order to implement a technical system.

Any technical system imposes implementation constraints on the functions it helps perform. When a new technical system displaces an old one, it does not necessarily bring with it the same set of implementation constraints as the old had. In the days of horse-drawn transport, towns needed to be close together, no more than twenty miles or so apart, and limitations on manure disposal, along with plodding speeds, would keep contiguous urban concentration from becoming very great. Trains and cars changed those constraints, reducing the need for provincial towns and facilitating the concentration of population in metropolitan centers and associated suburbs. Big cities got bigger and small towns smaller because the implementation constraints of the old transportation system were not carried over into the new.

Implementation constraints are features built into a system in order to make it work effectively. These features do not reflect characteristics that are necessarily desirable, in and of themselves, nor are they always disadvantageous. They are tolerable components of a workable solution, enabling people to make good use of the feasible technology, but in doing that they also set limits on the performance of the system. Significant implementation constraints can last, unchallenged, for centuries over great areas, and then suddenly disappear when new technologies free from those constraints displace the old.

Consider, for instance, architecture. Until recently, in every culture in every part of the world, implementation constraints made it very rare to build a structure more than five stories high. Occasionally that would be done for reasons of monumental ceremony as with various pyramids, or of communicational reach when the muezzin calls people to prayer from the minaret or the cathedral bells toll across the town from high in the belfry. With pre-mechanical architecture, implementation constraints almost always worked to keep buildings low: tall structures were expensive to build and people found them a chore to use, having to run up and down many flights of stairs. Hence it was a natural practice to limit ordinary buildings to a height of five floors or less. In the late nineteenth century, the implementation constraints limiting the height of buildings vanished as new materials, new principles of design, and new resources such as elevators, electric lighting, and central heating and ventilation, all made structures built to an unprecedented scale rapidly feasible. Now in urban areas round the world buildings scaled to the old constraints are exceptions to a completely different rule.

In retrospect, it is usually easy to see implementation constraints for what they are, limiting characteristics of dominant technologies. But from within, while a dominant technology is still hegemonic, it is often difficult to see its implementation constraints as such. Instead, they can appear to be part of the natural order, artifacts, not of the technology, but of the natural laws and necessary conditions on which the technology rests. Thus, it was an implementation constraint of human transportation that no one traveled much faster than the speed of a galloping horse until the early 1800s. When trains started to puff along at speeds that left horses wheezing behind, commentators argued that the unprecedented speed was unnatural and dangerous to the humans who subjected themselves to it, not because the train might crash, but because the speed itself menaced the human constitution. From the perspective of the experience then available, evidence derived from the effects of tornadoes and hurricanes seemed to make the warnings plausible. Of course, there proved to be easy ways to shield riders from the winds of speed and the argument that speed itself was harmful proved absurdly false. Yet it illustrates how difficult it can be, from within a technical hegemony, to see its implementation constraints for what they are, mere accidents.

In an educational system designed to take advantage of printed resources, implementation constraints make educational experience simultaneously fragmented and limited. These implementation constraints will seem to many to be natural necessities, but they are not. Schooling becomes a scattered intellectual experience because of the way the culture must be fragmented into many subjects, with these sequenced for study year by year, in order to implement the use of textbooks in education. It becomes limited because the total selection of the culture that can be included in the official texts is very restricted. Thirty volumes is not much relative to the total range of possibilities. These implementation constraints have dire effects on the nature of curriculum politics and they confront many students with very difficult tasks of integration. They make educational effort less liberal and less integral than it could be.

Through an integral education, a student forms her judgment by integrating her engagement with the culture, forming convictions, preferences, valuations, explanations, understandings that she uses to define herself and her world. To achieve an integral education, a student should construct connections, but our system of schooling produces partitions. As we have seen, to use textbooks, an annual packaging of separate subjects is a necessity. Occasionally students in a subject will spend two or more years on a single text; sometimes they study several shorter texts in one subject in one year. But the norm is one text per subject per year, and this norm exists, for reasons of neither developmental psychology nor cultural coherence. It exists to make textbooks usable.

Imagine students having at hand one gigantic, comprehensive set of texts, covering all subjects from kindergarten through high school, The Complete Compendium: Everything You Can and Should Learn In School. No student could handle the whole set, day by day, and its volumes would not fit in his desk or locker. The material constraints of using books requires segmenting the student's intellectual experience into annual increments. As a result, at best, the student passes through the curriculum, visiting each unit productively in turn. He cannot easily go back to material he studied a couple years before but did not quite get down pat, and he cannot easily reach forward in the sequence, suddenly alert to something slated for use two years hence. Educators often complain of this tendency to lockstep progression, but it is hard to avoid at least in part because it is rooted in the material constraints of texts.

A complex culture can sustain innumerable paths of inquiry in and through it, each with its logic and integrity, where one thing leads to another because a specific rejoinder to a student's particular question leads to further wondering, and then to ensuing responses, new doubts, more solutions, and so on. Individualized learning develops from the inside out in this way, as a student integrates responses to her questions into an understanding that she recognizes to be her own, full responsibility for which she asserts. Historically, the way printing amplified the availability of different texts, enhancing too their quality and dependability, greatly accelerated the individuation of learning, enabling inquiring minds to follow powerful questions to productive answers to a degree that human cultures never approached before. But this great advance had limits, and we can now feel these chafing our pedagogical aspirations. The very accomplishments of the book lead us to want to go beyond the span of pedagogical possibility inherent in it.

Individualized learning is a long sought, imperfectly achieved, educational ideal. The sequence of annual curricular increments greatly complicates the individualization of learning, for it imposes on everyone a single, arbitrary, over-all order. Jenny is fourteen, entering ninth grade, and she will therefore start algebra, do biology, and learn about the Greeks and Romans, because those are things her school covers in the ninth grade. If she does biology this year, it will be chemistry or physics next, not the other way around. Are biology, chemistry, and physics really separate subjects? Well, yes and no. There are surely separate textbooks for each, and universities organize specialists in each in separate departments. They work in different labs and use different instruments, and they read different journals and attend different conventions. But the practicing biologist will draw continually on knowledge of chemistry and physics and it is hard, given any real question within a discipline, to confine the discourse pertinent to it strictly within the bounds of that discipline alone. At the least, it would be helpful to do biology with the chemistry and physics texts close at hand, along with the one for biology, and much else as well. That rarely happens for the ordinary student.

Thus textbooks reinforce tendencies to fragmentation in the intellectual experience of the culture -- this today, that tomorrow. To package the culture for presentation through texts, we cut the life of the mind into pieces, put defining covers around each, and dole them out one by one. This piecemeal pedagogy makes it hard for a student to integrate her studies. The day is riven into periods: the bell rings for English, fifty minutes for As You Like It, whether or not you do, then the bell again, signaling the sudden end of English and the abrupt start of Math. Such a way of organizing work objectifies arbitrary distinctions and makes it hard for a student to take full possession of her learning. It is a tribute to the formative, integrating powers of the human mind that schooling leads as often as it does, despite its false segmentations, to well integrated achievements by its students.

In addition to systematically dissipating a student's intellectual focus, the implementation constraints of printed texts put severe limits on a student's curiosity and concern. This weakens the student's integrative capacities. Only a small part of any subject can be included in the text. What is not included does not count, even though it might break Billy's boredom. As they move beyond the first few years and become acculturated to competing for grades, students themselves often collaborate in their boredom, for they know the system in which they labor. When an enterprising teacher introduces an unexpected and provoking topic, one that they sense probably is not included in the official epitome on which they will be examined, the murmur rises -- "Gee, this is kinda interesting, but are we responsible for it?" The retort should resound -- "Yes! You're responsible for this and the whole of your lives and your world, for everything, and you must judge what things you encounter will prove of worth to you in it." Instead, the honest teacher, also knowing the system, answers with a apologetic nay -- "Well, no, but I thought it might interest some . . . ."

Bored students do not integrate their learning well. They instead miss the point and soon forget whatever they sponged up because it would shortly be required of them. The world system of schooling has everywhere a curriculum made up of desiccated fragments that lack sufficient depth and variety to engage a student's curiosity fully, not because such a bland curriculum is a natural necessity, like pabulum for babes, but because the implementation constraints of print-based instruction permitted nothing else. These implementation constraints make it difficult for students to achieve an integral education. Likewise, they divert effort from liberal education.

Through a liberal education, a student develops the capacity to acquire further knowledge, skill, and understanding without dependency on others. Such responsible self-direction is the mark of the autonomous person. A liberally educated person, confronted with a new challenge, knows how to find resources, has sufficient intellectual self-confidence to sense what he needs to know in order to proceed, can judge what is relevant, can comprehend new material, and work through the difficulties he encounters without depending on external authority for guidance. A liberally educated person has learned to learn, and can respond, a free, self-directing person, to the challenges life puts.186 Significant implementation constraints of print-based schooling discourage attainment of a liberal education. Too often educators seem to propound the fiction that to master any subject, one must learn its official epitome, and the teacher's role is to carry the student systematically through the epitome and to certify his mastery of it. At each step, one might expect interest in having students demonstrate their ability to reach out and grasp new issues and ideas, but testing is often habitually retrospective in orientation, designed to make sure that the student knows what he is supposed to know, where knowing consists in reciting back what has been taught. When this system of testing is decadent, progress through it is entirely passive, simply a function of the student's aging, year by year. When it still has some vitality, progress through it depends on demonstrating command of the given increment, good marks all along, capped by passing the "final exam," an oxymoron if there ever was one, for the final exam recurs term by term, year by year, subject by subject. Incessantly testing whether the student knows what has been taught does not cultivate the idea of a liberal education. Instead, it insinuates the slavish belief that only external authority can validate one's learning.

Of course, within this world numerous teachers work interstitially with interested students to develop powers of self- directed inquiry. But such teachers are often on the defensive. Apologists of the status quo claim that at least their way has the virtue of accountability, whereas practitioners of liberal education spout high-minded platitudes the attainment of which can never be measured. In principle, it would be easy to test whether a student's education is liberal, for all one needs to do is pose new challenges to her and see whether she can independently acquire the intellectual resources needed to meet them, finding suitable materials, advice, and explanations. In practice, such a test has been hard to implement because the intellectual resources manageable in schooling have been so restricted. Problem-solving does not lend itself to textbook presentations. Testing in the print- based system does not even map the full range of what a student has learned; it probes instead how completely the student has learned those materials that authority deems essential, required. Such testing encourages servile, not liberal, education.

Information about how ready a student is to tackle different sorts of problems independently would better benefit the clients of schooling -- colleges, corporations, parents and students themselves, the public at large. Critics and commentators insist that problem-solving should be the focus of the schools, the purpose of which is to help students learn to learn. These strictures signify the importance of liberal education, which can have, not only significant spiritual meaning, but also a real cash- value in a fast-changing world of pragmatic action. The implementation constraints of the current system, however, are fundamentally inimical to these goals. Problems exist as open-ended challenges and one cannot engage in solving them where the scope of relevant material is radically circumscribed and the sequence of its presentation choreographed step by step. Yet we pretend that each student should learn the same thing as any other student as they march year by year through the school curriculum. Why do we do this? That is all that print-based schools can manage. People may have seen it as a natural necessity of sound education, like never moving faster than fifteen miles-per-hour. But really it is a simple implementation constraint that comes with basing the process on a predetermined text. Can it now be done some other way, one that will discard these well-worn implementation constraints?

Navigating Networked, Intelligent Multimedia

Technology is not now entering education for the first time. The schools embody a mature educational technology based on printing. To develop the uses of digital information technology in education, the established technology of schooling will need to be displaced. That can now happen.

Imagine a thoroughly computer-based curriculum. It will reside in a system of networked multimedia. Each student will link to it with a notebook computer. Additionally, small-group workstations will be ubiquitously available, on average one for every four students, and one per teacher. These will be high-powered systems capable of delivering quality multimedia presentations while multi-tasking complex programs in the background. The networking will be very high speed, sufficiently powerful to provide each workstation with its own stream of digitized, interactive, full-screen video and good audio. The library of materials available through the system will be extensive, consisting of a full cross- section of the culture in all its branches and varieties and effective tools to aid its study. These materials will reside primarily on an advanced server system for the school on the premises, with integrated, high-speed links to other servers, near and distant, so that members of study-groups can call for most any material they want and receive it with insignificant delay. In addition to the small-group workstations, all spaces will have appropriately scaled projection monitors or large, flat wall-displays for showing material to larger groups.

For our purposes, the particulars of this system are less important than the order of capacity that they indicate. In a fully digitized culture, the educational resources of the school will be ubiquitously available and they will be far more extensive and powerful than those currently available. With this order of capacity, we can indicate quite precisely how this environment will differ pedagogically from that experienced in print-based schools. Two features of it will be most important.

> » First, all the materials pertaining to the curriculum will be accessible to any student or teacher at any time. The curriculum will cease to be a sequence of compartmentalized units. » Second, the scope of the materials included in the curriculum, while not boundless, will be much greater than the thirty stout volumes that it currently can comprise. The curriculum will provide multiple paths to the highest levels of achievement in all domains of the contributing cultures. These two features -- a transformation of scope and a transcending of set sequence -- will profoundly alter the implementation constraints of the current system, radically changing its pedagogy.

With all the school's intellectual resources accessible to all students and all teachers at all times, the curriculum will change profoundly. Currently, the place where all the school's materials might be found is in the school library, which students can use, for practical purposes, only on a limited, exceptional basis. When all the school's materials reside in a multimedia electronic library, accessible interactively over a high-speed network form any place in the school, the library, not the textbook, defines the scope of all the subjects. In effect the student, from his desk, can reach instantaneously into any part of the library, which defines suddenly the universe of knowledge and ideas that a student might study and learn.

This change will have a profound effect on everyday pedagogy, for teaching and testing with reference to a text is very different from what teaching and testing with reference to an electronic library will be. With a textbook, learning means coming to know its content; with a library learning means grasping how to find, retrieve, and understand materials in it that one judges relevant. With a textbook, people generally presume that good students should master all that is in them, although teachers generally decide to leave parts out and to change the weighting of emphasis. And with the practice of "curriculum alignment," the expectation is even spreading that textbooks should include only those items likely to appear on major tests. The rest is a distraction! Currently, teachers plan the sequence of lessons to ensure that students cover the subject, with each mastering as much of the totality included as possible. Of course, the "subject" here is not really the subject, but the sanctioned epitome of it that the syllabus and its associated texts comprise. In reality, the subject includes much, much more than that, which would be found in principle, not in the appropriate textbook, but in the relevant part of the library or in university departments and labs.

A student who finds his subject in a library does not work in the same way as he works with a textbook. A decent library should have many more resources in it than any individual or group can exhaust. If a student can master everything on a subject in a library, we must conclude both that the student is superhumanly able and the library abysmally poor. Learning to work productively in a library entails working in an open-ended realm where the student must make continual judgments about what to do and what not to do. He looks things up, browses, navigates through the many contributions to a subject, seeking materials that will contribute to his understanding of the issues at hand. The pedagogy appropriate in this context will differ from that used when the "good" student is to master everything in the assigned text.

In a computer-based educational system, all intellectual contents and pedagogical resources will be available to all students and teachers at all times, and those materials will be much more extensive and complex than they currently are. Together, these two changes will shatter the implementation constraints of the print-based system. As these constraints disappear, the span of pedagogical possibility will change. What people will be able to learn, what they will need to learn, and how they learn it will shift significantly. Let us reflect on how these changes may soon happen.

Chapter Five - Making a New Educational System

Big changes in key institutions are hard to launch, but irresistible once underway. They are tough to start because they need to be many-sided. Existing arrangements are a puzzle of many interlocking pieces. One cannot, for instance, simply replace textbooks with computer programs that do the same thing, only slightly better, for all sorts of other things will have to start changing as well -- classroom layout, teacher training, curriculum organization, the interaction of children in class, relations between home and school, possibly even the professed purposes of the school.

So far, innovators have scaled applications of the new technologies to education almost entirely to the conventions of current practice. It is as if architects had tested the potentials of i- beam frames, elevators, curtain walls, plate glass, and the like only in the construction of single-family homes and five-story brownstones. In tests scaled to prior conventions, the advantages would appear marginal. Interesting possibilities might emerge, but the full potentialities of the new architecture would be far from evident. Historically, architects built the case for new materials, not by improving familiar structures with them, but by putting up new structures that were previously impracticable, a wondrous Eiffel Tower, changing the span of architectural possibility.

High-rise cities have their beauty and sophistication, as well as their despair and discontents. If we use new technologies to create a new educational system, we receive no guarantee that in the most profound sense it will be better than the old, effectively generating a higher humanity. Changes in conditions and contexts are important, not because they compel the stakes of life to culminate in any necessary outcome, be it good or bad. They are important because they alter the dynamics of interaction, allowing the stakes of life to play out in a myriad of ways, some new, some old, some good, some bad. They refresh the game -- some losers become winners, some winners, losers; some visions that practical people could once dismiss with a snort become the realistic grounds for effective action. Changes in conditions shake the kaleidoscope of history, allowing new generations to struggle, again yet anew, with the great issues of meaning and value.

Educators are stuck, world around, with a big, mature system that is nowhere prepossessing in the way it functions. Cross- national comparisons of educational performance, pointing up significant differences in result, are an increasing obsession in professional and public discussions of education. They should not, however, obscure from view the fundamental structural similarities that make the comparisons possible and interesting. Any group of long-distance runners will spread out along a spectrum of performance, but their times will be comparable precisely because they are similar competitors running the same race. The task of technology in education is not to move an also-ran to the head of the pack; the task is to substitute a new, distinctly superior spectrum of performance for the old. That will refresh the game, allowing us to return to the issues of human worth and purpose.

Let us to break away from the structural limitations of the current world-wide system of schooling. Like architecture a century ago, we can make this break because we have new resources with which to work, suspending traditional implementation constraints. We aim to make a new system of education, one different from the system of print-based schooling that has dominated educational effort for the past five centuries. To make such a departure, five components essential in the construction of the given system need to be redesigned with full awareness of the potentialities of information technologies in mind.

> » How should we organize educative activity in space and time to make full use of information technology? What should its location and schedule be?

> » What well-springs of human emotion and activity should it tap for its driving energies?

> » How should we manage the works and knowledge of our culture so that

presentation of them through advanced information technologies will best support the educative effort?

» What pedagogical resources will best enable students to explore, select, and appropriate the skills and ideas that the culture proffers to them?

» How can we structure the activities of teaching so that they attract highly talented people and provide them with self- renewing and self-developing conditions of work?

These questions will lead us into considering a complex system in which multiple sets of arrangements function in reciprocal interaction. We will survey this complexity by attending to five distinct topics -- environment, motivation, culture, educational method, and staffing. The constraints of discourse require that we do this in an order, first one then another. Despite this apparent sequence, these topics are, of course, simultaneous facets of a single system. Our isolation of them, one from another, occurs through abstraction in discourse, not in fact. After discussing them in an arbitrary order, we will need to remind ourselves that they coexist in complex interaction.

Educational Design of Learning Environments

We need a starting point: look first at the environment, the organization of educational space and time, not because it is necessarily fundamental, but because it is perhaps the most visible. The basic unit of school space is the classroom, world around. It is scaled for one teacher and an appropriate number of students, about twenty-five, plus or minus 50 percent. The basic unit of school time is the period, which aggregates into the school day, which in turn aggregates into the school year. The period is essentially an hour, including transition time between periods, plus or minus 25 percent, with occasional use of double periods. How can information technologies help alter these basic units?

Taking the problem of time and space first, we cannot be as conclusive about it as we might like without anticipating other matters such as motivation, cultural content, and educational method. In this section, we will consider only how new technologies can open options with respect to the organization of the school. Three concepts will be key in the discussion: asynchronous space and time, responsive environments, and virtual reconstruction. By asynchronous space and time, we mean the ability of people, who are not synchronized in the same place at the same time, to communicate easily with each other in a variety of responsive ways. By responsive environments, we mean the ability to endow spaces and periods with an electronic responsiveness to the particular people in them, with the spaces and periods adapting what is in them and how they are organized to the needs of their particular users. By virtual reconstruction, we mean the ability to use interactive multimedia components to redesign and reconfigure the human experience of existing physical spaces without having to make physical, structural changes in buildings. Asynchronous space and time, responsive environments, and virtual reconstruction can powerfully transform the way schools work.

Existing schools can be viewed as a means for synchronizing diverse activities in space and time. That is what scheduling is all about, and within a particular class, a teacher needs diverse arts for synchronizing effort on the subject at hand. Schooling at its best centers on developing students' skills and sensibilities. In settings controlled by this purpose, the interaction between teacher and students will involve open-ended questions, discussion, and attention to the processes by which students work -- individually and in groups. The class, when conducted by an adept teacher, will have a powerful rhythm and flow, with different students taking different parts at different times, the whole being an intensely choreographed experience, with all taking part, but some taking a more central part than others. Here coverage, in the sense of each student getting a full opportunity to try all the steps in the program, will be at risk, and such coverage is the very thing that school space and time traditionally work to guarantee.

Consequently, the system gravitates to a different, more ponderous synchronization. During the typical period, in middle or upper grades, with attention to coverage increasingly controlling, the interaction between teacher and students will consist largely of recitation, a process in which the teacher incites students to display their command of material and evaluates their performances, good, bad, or indifferent, relative to each other. Recitation may be preceded by explanation in the form of lectures or demonstrations, or it may be based on homework on assigned materials. Recitation may be in the form of verbal answers to questions, with students called randomly or vying for the teacher's attention, or it may be in the form of written quizzes and tests. Whatever the form, the opportunity arises for recitation because a teacher has assigned a unit of material to his students, for mastery of which they are responsible, and the function of recitation is to probe and reinforce that mastery. The underlying idea of synchronization here is that all are doing the same thing at the same time, with the students and teacher marching briskly through the material all in step with one another.

Educational computers can provide asynchronous supports for both forms of synchronized classroom interaction, recitation and discussion. Drill and practice systems allow students to get the benefits of systematic recitation without having to be synchronized in space and time with their teachers or their peers. These programs allow each student to pursue them at his own pace and, in a properly networked environment, at a time and place of his choosing; he does not need to suffer ridicule should he bumble or incur impatience should he be slow; nor need he linger in glazed boredom should he have it down pat while others wrestle laboriously with the items to be covered. Drill and practice programs may have a significant liberating influence in education if they help open the existing organization of space and time, making it unnecessary to group students for recitation in order to guarantee them suitable coverage.

In like manner, computer networks can support a great deal of complicated, inter-personal activity, discussion, that is asynchronous in space and time. Networked multimedia systems will increasingly allow any person, anyplace, to enter into face-to-face exchange with anyone else with remarkable flexibility in time. Currently, electronic mail gives an indication of what will emerge, for it significantly alters the temporal and spatial frame within which consultations between students and teachers can take place. Like the telephone, e-mail allows people to interact independent of place, but unlike the telephone, which requires both parties to be synchronized in time, e-mail does not. Digital-video-mail will gain much of the immediacy of face-to-face interaction, while allowing the parties to be most any place and with a very flexible linkage in time. An intensive, many-cycled give-and-take can occur without the parties needing to be synchronous either in time or space.

By complementing synchronized interactions with a full capacity for asynchronized ones, the physical constraints impeding one-to- one consultation between a teacher and a student can be greatly lowered, and all sorts of new pedagogical groupings may become both feasible and effective. For instance, team teaching is likely to take on more powerful, central significance, with perhaps four teachers -- specialists in language and literature, social studies, science, and the arts -- working the whole day, each day, throughout the year, with a class of eighty to one hundred students, who in small groups would be cooperatively pursuing several long-term projects. Their activity might be spread across several rooms, with everyone moving back and forth between synchronous and asynchronous interactions concerning their tasks at hand -- a face-to-face question leading to a computer consultation and the posting of three e-mail queries, with the answer to one resulting a few hours later in a new subgrouping, and so on. Such an educational space would be much more like an atelier, a design studio, or an architectural office, than the present-day school. Whatever it comes to be like, or unlike, one of the major tasks for educators will be to discover how to adapt the asynchronous powers of computer communications to their pedagogical purposes.

Responsive environments will be a second major means for using information technology to reorganize educational time and space. What is in a name? Each student has one. A teacher fails to be responsive by not learning his students' names and being unable to recognize who each is, what interests them, what their hopes and fears may be. Kindergarten and elementary classrooms, home rooms, develop a marvelous clutter of things here and there and all over the walls, things of meaning to teacher and pupil alike, things responsive to their interests and activities. In middle and upper grades, as students and teachers increasingly move from room to room according to the dictates of the schedule, the environment becomes less personal, an anonymous space occupied for an arbitrary time. Information technologies can do much to make these surroundings more meaningful, more responsive to the people at work within them.

Even with the current state of the art, people who work regularly with a particular computer will customize the electronic microworld that it presents to them. Someone adept with her computer will have her selection of software on it, not just any selection, and over time she will have configured that software to reflect her preferences. She will arrange it on disks the way she likes it and associate programs with icons so that she can manage them without breaking her train of thought. She will build up a complicated sense of electronic space filled with all sorts of objects and functions that she cannot see, but that she has a sense nevertheless of how they orient to each other, and to her, rather, perhaps, like the sense of familiar rooms that a person who is blind builds up. With a few strokes, she can run little programs that reconfigure her working space from one project to another, much like she does when she moves from one room to another. The electronic environment need be neither anonymous nor arbitrary.

Such personalization of the electronic environment can carry over from the personal computer to a network. When the user logs onto the network, he activates configuration programs that set the environment to his style and need, regardless of where in physical space the workstation may be. Portable computers also give an experience of this movable amenity -- pop, in a distant city the familiar electronic work space is right there. These intimations of the possibilities are merely snapshots taken at the base of an ascending curve of innovation. Current networks are slow and awkward; portables are cramped and self-conscious. In due course, before the first-grader is into secondary school, computers of diverse sorts will be all about, hanging on the wall like pictures, encased in a slim writing pad, slipped in a shirt pocket, standing there as a powerful workstation. As we take up Hamlet, the workstation at my place senses who I am, greets me, remembers where I left off two days before, and, along with the rest of the computers in the room, reconfigures itself to reflect the topic and the participants, the wallboards cycling silently through heuristic images, each person's notepad retrieving his jottings, and the workstation nearest the newcomer to the discussion running a quick recap for her.

Pedagogical environments can be made responsive in all sorts of significant ways, large and small. These do not require any great advance towards artificial intelligence. On the contrary, most of it simply involves keeping track of who is who and who needs what, where and when. Essentially, in a well networked system everything is physically in only one place, and it can appear logically, virtually, wherever we wish whenever we wish. Think of all the excuses -- "I lost my homework instructions. . . . My dog ate my paper. . . . I left my book at Jimmy's and Mom wouldn't let me go back for it. . . . Its in my locker. . . . I went to the library but it was checked out. . . . Oh, I thought we were to do page 153, not 143. . . . I missed last class and no one told me. . . ." With a well-networked computer, students should be able to avoid these plights because the educational environment will be more responsive to them.

These forms of responsiveness will become possible because networked multimedia will provide each student access to all the school's educational resources at all times. Another form of responsiveness will become possible because the scope of those educational resources will be much greater than it can be in print- based schools. Philosophy begins in wonder, the ancients said. But it is hard to nurture adequately the wondering of many different students. Informed teachers, school libraries, trips and travel, all help feed the collective curiosity of the student body. But they are hard pressed, under stocked, and infrequent. As a place experienced and as time spent, the school is too often not the locus of wonder in our young. The regimen of the school is historically old; its effects predictable; its ethos all too often fails to command attention and engagement.

To what degree does any given school pulsate as a source of information and stimulation about the world in its full complexity? Many alternative activities -- television and films, after-school work, hanging out in the mall, radio and a ride around to a concert and back -- may actually provide more stimulus to amazement and respect than does the program of the school. Relative to the world of the twenty-first century, existing schools are narrow and simplistic. Television news casually girds the globe and reports historic events from every different culture and commerce brings every manner of product from every manner of place into supermarkets, malls, and mail order catalogues. If these are the cultural wastelands, what are the schools? To transmit the culture, schools must drive the culture, energizing and advancing it, celebrating its ideas and energies more vigorously than other institutions. A robust school that offers access to the whole culture, in all its complexity and richness, through networked, interactive multimedia may regain a lost luster as the main means by which the young can assuage their collective curiosity. To be a fully responsive environment, the school should be the place with the aura of wonder and excitement for the young and the school's time should be the time of anticipation and fervor: the school needs to throb with knowledge and inquiry, with a confident mastery, acknowledged as the locus of creative innovation crafting the common future. Then, indeed, it will be a responsive environment.

Virtual reconstruction will be a third means for using the computer as a system to remake the time and space of schools. In order for innovations to have a substantial, transformative effect on education writ large, they need to be introduced on a wide scale in a concentrated, short period. In a significant transition, there may be a long initial period of gestation, and a long, concluding period where new arrangements reach saturation. But between, when the innovation genuinely takes hold of the world of practice, it needs to spread rapidly, being introduced coherently in many different places over five to ten years. Educators have great difficulty sustaining such a process. Developed societies have huge capital investments in school buildings. These are real structures with corridors and classrooms; electrical systems, plumbing, ventilation; labs and offices and music rooms and a melange of acquired stuff, all designed to function efficiently according to established pedagogical practices, built to last, usually to institutional standards, financed through bond issues and mortgages with long pay-out periods. Over-all the capital replacement cycle in education is fifty years plus or minus and it is hard to focus innovative energies within it.

Reforms that propose alternative designs of time and space, curiously, find no dearth of pioneers. School construction is always going on and many communities prove eager to dress the process up in ideas of reform and renewal. The problem arises when the innovation, to sustain its own dynamism, needs to spread more rapidly than the capital replacement cycle will allow. At first the proposition is easy: "we need a new lower school; let's design it according to the British infant school model." Soon the proposition elsewhere becomes more difficult: "It was just finished! If it means major renovations to the lower school to adopt the British infant school model, we're going to wait until the evidence is more conclusive than it seems to me to be." The capital replacement cycle probably has a great deal to do with the tendency of educators to wax enthusiastic about potential innovations and then a few years later to wane in disillusion with them.

With respect to the capital replacement cycle, the computer as a system has very interesting characteristics. While it is easier to build information technologies into new construction that it is to retrofit existing buildings with them, the difference is not that great. Ocean-going steamships long carried a full complement of sails, and it may not be unwise for electronic schools to be able to function, when appropriate, in a traditional print-based style. If educators can redesign educational space and time with electronic technologies, leaving the existing physical spaces of the school intact, functional if not optimal, then they will have disengaged the innovation cycle from the capital replacement cycle. That will greatly enhance prospects for success.

In doing this, the concept of the virtual is very important. Computer specialists often distinguish between physical devices and logical or virtual devices. In this sense, computer environments are profoundly relativistic. Physical devices are the manufactured, material components of the system. Logical or virtual devices depend on the way those physical components have been configured to appear to the user. There may be one physical storage device, for example a high capacity fixed disk drive on a computer, but it may be configured to appear as several different logical devices, drives C:\> and D:\>, to the user. Conversely, several physical devices may be configured to appear as one virtual device without the user needing to know where those physical devices are and how information he saves is divvied up between them. Very shortly, the virtual reconstruction of spaces will become widely feasible, with physically distinct spaces being joined into virtual rooms where people in different locations can interact as if they were together face-to-face. Schools are likely locations for these developments.

Networks provide the first set of possibilities for virtual reconstruction. Imagine that a school district's science faculty decides to try a multi-grade project involving students from the third, seventh, and eleventh grades. Let's postulate that this is not a little side project where a couple high school students and a few from the intermediate school go to the elementary school for a few hours each week. Instead, it is to be a big deal involving all the students in each grade, each day, buttressed by theories that young children can learn well from older children and that older children can learn well by trying to teach younger ones and that they will form a stronger sense of responsibility and purpose in the process. With each grade in separate buildings, such a plan is nearly unthinkable in traditional contexts unless one were to contemplate the complete redesign of the district's school buildings. With intensive networking and good video conferencing, such an experiment would not be impossibly difficult to configure and there would be relatively little need to restructure the existing school plants. This would be an instance of virtual reconstruction.

All sorts of ways to reconfigure time and space electronically will rapidly arise. For instance, the cost of large flat panel displays that can hang on a wall are decreasing and these can be used to join spaces that stand adjacent, or even half way round the world, in very responsive ways, where glances at one another across the virtual room can meet in a smile and a blush, a nudge and a giggle, or small groups, half here and half there, can converse in a virtual corner. It would be, thus, a strategic mistake of the first order to think that we need to physically reconstruct all the spaces of education in order to adapt them to the use of electronic technology. Rather, we need to use the electronic technology as fully as possible as new architectural elements to create new virtual spaces within the confines of existing physical structures. In this way, the innovation cycle can be set free from the capital replacement cycle and the transformation of education can follow apace.

Multimedia information technologies with powerful networking, tracking, and scheduling capacities can make the very flexible use of space and time possible. For a new system of education to emerge, educators, working closely with established and emergent schools, will need to experiment with such flexibilities, learning to use asynchronous space and time, responsive environments, and virtual reconstruction to further the deepest educational purposes. From the present vantage, we cannot predict the precise features of the innovations that will prove successful, but, one way or another, as educators act on the intuition that new technologies will enable them to reshape pedagogical space and time, they will develop a more effective environment. We are dealing with in- novations that invalidate the common sense that held under prior conditions; our task will be to develop a new common sense, suitable for the new conditions. With the old common sense, edu- cational environments were standardized and predictable; with the new, they will be flexible, diverse -- a challenge to the imagination. The same will prevail with the strategies of motivation at work in these new environments.

Motivational Sources of Education

Think of a fifth-grade classroom. Imagine the class dealing with virtually any subject. The teacher has just provided an explanation of a key point summarized in the text. She asks a question -- some pupils raise their hands and wave eagerly, confidant that they know the answer. Some sit in a studious effort to avoid attracting the teacher's attention, knowing that they do not know and not wanting that fact to be registered in the public knowledge of the teacher or the class. Others seem neither eager nor reluctant, they fidget, raise and lower a hand in ambivalence, thinking they know the an- swer but not being sure, wanting to earn the teacher's commenda- tion, but fearing that, if wrong, they risk rejection or rebuke. These are the signs of instructional competition at work. From the early grades through the highest levels, the existing system motivates children by engaging them in a competitive effort to shine in recita- tion and examination, in which each tries to show that he or she has mastered better than others the information sanctioned to be fit for his or her level and to be correct in the view of academic authority. As a result of this reliance on competition, the educational system functions as a powerful sorting mechanism, and when it becomes clear to many that however they may try, they have lost the competition, they drop out.

It is remarkable how thoroughly existing educational systems, around the world, have been adapted to harness competitive motivations. It is very hard to find arrangements in schools that have been designed to encourage children to act from other motivational sources. Undoubtedly the reasons for this reliance are complex, and certainly one among them is the important fact that competition is a very powerful, effective motivator. But there are other powerful motivators, among them cooperation and it is remarkable how few educational arrangements have been de- signed to motivate children to learn through cooperation. The reason for this imbalance between competition and cooperation may have had much to do with the logistics of working with printed information.

Think of a ninth-grade teacher, preparing a unit on feudalism, lamenting -- I can't have them do group projects. There just aren't enough worthwhile materials reasonably available to them. New York City has all sorts of resources, but it doesn't really help -- those who would need to go to the Cloisters wouldn't be able to get there without all sorts of complications. The school library is good but inadequate and they can't just simply use the high-school annex to the New York Public Library -- we either stay in the school or arrange, all together, to take a trip. How do I get some to the Met, others to the Morgan, and a couple into the stacks at Butler Library? How can projects be done at a high academic level in a routine way?

If it is hard to do group projects at a high academic level in a routine way in New York City, it is far harder, most other places. Sadly, serious information management problems discourage inquiry and cooperative learning, problems that must be solved if these alternatives to competitive learning are to become practical, everyday alternatives in mass education. Competitive motivation arises when a group of students start from an appropriately equivalent basis, usually as measured by age, and each is then asked to master a limited, standardized body of material, with goods -- praise, grades, promotion, and acceptance by the college of choice -- being distributed in proportion to how well, in comparison to others, each performs. From the point of view of information management, this practice is very efficient; it is essential in establishing the comparison that all work with the same body of subject matter. This creates a large market for inexpensive, well-chosen, clearly-presented selections, which textbook publishers compete to provide.

Cooperative learning does not make sense in situations where each student starts with the same content with the goal of mastering more of it than anyone else. Cooperation aims at having participants do different things and then coordinating their accomplishments in a common achievement that exceeds what each would manage alone. In educational situations this puts far greater strain on the information resources available to the cooperating participants. Ideally, for robust cooperative learning, students should face an expansive horizon of questions, armed with extensive resources to pursue their inquiries in many directions to considerable depth. If the questions and resources available are limited, their cooperative effort will not make much sense and different members of the group will find themselves working at cross-purposes with each other, repeating each others' efforts, and vying with one another to do the most with the few resources on which all converge.

For centuries, educational reformers have contended that cooperative learning would be a good thing, and occasional examples of learning by working together to solve real problems keep the ideal alive. It has been very hard, however, to provide the intellectual resources to sustain good cooperative learning in most educational settings. The practice has worked best with the very young, where relatively limited materials will sustain the effort, or at the most elite levels of education where bountiful laboratories and libraries sustain the extensive specialization of inquiry that cooperative learning generates. For the age between these extremes, cooperative learning has been very difficult to implement. What materials will be needed to have twenty fifteen- year-olds do a two-week unit on feudalism according to the principles of competitive motivation? Each will need a copy of a well-written text and regular attendance to a teacher who can provide supplemental explanations, moderate exploratory discussions, and then manage recitations and a test. What materials will be needed to have those students spend two weeks cooperatively exploring the history of feudalism, drawing together at the end a presentation of their results? The range of possibly pertinent materials is nearly limitless and the possible roles a teacher might take in the effort are almost boundless. Consequently, the information logistics of cooperative learning strain the print-based system.

Electronic information management technologies will significantly diminish the logistical constraints on cooperative learning. One of the simplest examples of such change involves the problem of movement. Traditionally, inquiry meant that children had to leave the classroom to go to the library or other locations of specialized resources. This usually was not efficient, introducing confusion about who was where and wasting time in excess movement. With inquiry in a well-networked electronic environment, the children can access specialized resources, almost instantaneously, with very little waste of time or effort. Such changes in logistics can have profound effects on the experience of working together. Traditionally a simple decision -- "I'll get this and you get that" -- would draw a cooperating pair apart, often to quite different locations, perhaps with one getting stymied on the way, but unable to tell her partner of the problem until long after either could do anything about it. In an electronic environment of information management, the two can allocate their effort while remaining in close proximity, physically and intellectually, often checking on the implications of what each is finding for the other.

Questions of motivation link profoundly with those of assessment. As the logistics of cooperation often impede cooperative motivation in education, so the character of assessment discourages it. To be blunt, cooperative behavior in competitive testing amounts to cheating. And many believe that the way schools sift talent through competitive testing is one of the main social functions performed by the educational system. Let us examine the case.

Credentialing through education may, in fact, be a poor way to distinguish who can best do what work. Credentialing may not be a function performed by education; rather it may be a function performed for education. Numerous important domains develop effective distinctions about who can do what without much recourse to educational credentials. Exclude the educational drop-outs from the computer industry and you would exclude a great portion of its talent. Businesses, which have a high stake in promoting people according to their capacities, do not usually do so by recourse to competitive tests. Rather, they observe how employees perform under diverse conditions, often in situations where each must cooperate with others to get a job done. Far from existing in order to credential capacities through competition, schools and society may engage in such credentialing for a quite different reason.

Consider the following hypothesis. Effective schooling is important to the smooth functioning of an industrial, bureaucratic system. Compulsory education laws reflect the importance of such schooling and they are difficult laws to enforce. Schooling as it exists is not intrinsically engaging to many students and they need extrinsic reasons to bear with the drudgery of getting an education. Police power is not a very effective way to enforce compulsory schooling laws and most societies try to advance other, more positive incentives and rationales for conforming to educational expectations. One way to develop such incentives is to attach educational credentials as preconditions for many types of employment. It is not that such and such education necessarily determines who can do the associated work, but often the reverse: qualifying for an inside track to various forms of work provides the incentive for students, urging them to buckle down and reach such and such an educational level.

If education were more intrinsically engaging, and credentialing through competitive testing were not needed as an incentive, what might assessment then accomplish? Its first function would be diagnostic. Assessment currently inhibits good educational diagnosis: in the face of relatively predictable tests, students avoid taking risks and work systematically to gloss over their deficiencies. Would medicine have developed if people had strong incentives to hide their symptoms? Were education to be, like health, an unequivocal intrinsic good for people, they would want pedagogical assessments that were diagnostically effective, revealing their weaknesses in ways that would help them to take measures to improve. A second function of assessment, were education more inherently involving, would be demonstrative. Here competition might play a significant role, but it would be more sportive -- "Yo! Look! Here is what we can do!" When doing something meaningful for themselves, people like to show their accomplishments off to others in the hope of recognition from those who can appreciate the art and effort of the work. Here, the opportunity for assessment will lead a student to create a portfolio, presenting those accomplishments that best represent her skills and values. A computer-based system of education will need to provide students and teachers with good diagnostic tools and with ample opportunities for creating meaningful work, along with resources for preserving and presenting it to interested audiences.

Issues of motivation and assessment are deeply human issues. In making a new educational system with the resources of digital technologies, we risk paying too much attention to passing details of the technology. What is at stake with the introduction of computers in education is the human use of human beings, and the key issues are not technical. They are instead issues of political and cultural interaction, emotional fulfillment, and cultural achievement. Educators are passing through a portal of opportunity. Once they have defined the form of the technology, it will sternly reinforce the theory of motivation they have built into it. But for now, educational technology still has a protean motivational character. In giving shape to it, we should attend to the deep and difficult questions.

» How should we implement systems to support cooperative in- quiry?

» What size and structure for cooperative groups will work best for different ages and activities?

» How should students, teachers, and the public assess performance in cooperative settings?

» How should curriculum designers organize knowledge and tools of inquiry and expression in order to support learning by the members of study groups?

These, and many similar questions, need serious examination in order to broaden the motivational energies effectively harnessed in a technology-intensive educational system. The same primacy of the human issues over the technological will be evident as we consider how educators should organize the resources of the culture for use in a computer-based system of education.

Organizing Culture and Knowledge

In making a new educational system, the most difficult task will be reorganizing the culture to adapt it to the use of digital technologies. This assertion can be easily misunderstood. It does not mean that the computer as a system should suddenly become the controlling reference point in making cultural choices. But it does mean that the computer needs to be taken into account in the process. It should not determine what the curriculum comprises, but it will shape how educators organize the materials of the curriculum, and the effects on that may be sufficient to alter weightings, making some current concerns insignificant and other matters, now trivial, quite prominent.

A similar assertion with respect to another domain can clarify what is at stake -- in making a system of automobile transportation, the most difficult task was redeveloping the road system and transportation support industries to adapt them to the use of cars. Where roads went still depended on where people were and where they wanted to go. But the design and engineering of roads had to change substantially -- surfaces well adapted to horses hooves were not suitable for cars and the livery stable had to give way to the gas station and the multinational companies that provide their products. To work well with computers, educators will need to redesign the curriculum through and through, still ensuring that it serves humane purposes, but transforming many of its characteristics, ignoring hooves, as it were, and attending to tires.

Consider one other point at the outset. Curriculum issues are presently controversial, with different visions of how educators should select elements of the culture for presentation to students at the heart of the controversy. To construct a curriculum, one must evaluate and select from the sum of human acquirements, narrowing the infinite range of possibilities to a finite field, one that nevertheless exceeds the power of acquisition of any individual by a wide margin. Debate about such selection now splits between proponents of "cultural literacy," who seek a fairly narrow, canonical selection, and advocates of "multicultural" approaches, who call for a broader, more inclusive selection. In thinking about making a new educational system through the material agency of digital technologies, our purpose should not be to advance one or the other side of this debate. The positions within it do not stand above the implementation constraints of the current system. The terms of the debate between cultural literacy and multicultural education will be reshaped substantially by the development of a new system of education that uses information technologies with full effect.

Within the current curriculum, we squeeze WASP culture as if it were in a cider press and then we sprinkle in cloves and cinnamon from here and there, casting Hispanic and other great literatures aside to rot unused. If very serious constraints on the scope of the curriculum did not exist, few critics would call for a canon nearly as narrow as that being now propounded. The real canon of worthwhile books by dead, white males who wrote in European languages greatly exceeds the capacity of any single student to master, but it does not exceed the capacity of the collective student body. So too for dead white females, or for blacks, or Asians, Indians -- whatever the adjectives. To put material into the traditional curriculum, one had to limit every field drastically, excluding most of what was valuable in it. To do that, one had to generate ludicrous arguments -- something to the effect that Dickens, or some other author, one among many peers, is the nineteenth-century English novelist that all our juniors must read, in one or another selected text.

If one can give students access to all the canons, each in their full scope, accentuating the works of greatest formative power in each, then students will have much better resources from which to choose. Where all the canons, in their full complexity, can be included among the working resources of the school, it is hard to fault the multicultural argument, that each student should be able to start her ascent through the resources of her culture at a point that recognizes and celebrates the ethos of her origins. We can accept the schema theory that proponents of cultural literacy advance, the idea that people need complex frames of reference, filled with suggestive particulars, in order to apprehend complex ideas actively. But it is only in the context of a culturally impoverished school that anyone need consider the proposition that a robust culture, engaging millions in its participant creation, need be founded on a single schema shared by all. The school should vibrate with variety. The electronic school will support numerous cultural literacies, between languages and within languages. With new technologies we can fill the school with a wealth of materials on a scale hitherto not contemplated, providing each student with resources for finding her unique way, in the light of her animating interests, through the wonder of possibilities. This is the promise of networked, intelligent, multimedia.

We can create a new system of education by redesigning schools to take advantage of networked, intelligent, multimedia. Each of these terms signifies technical developments that will have significant effects on the cultural selection of the curriculum. That everything is networked will radically change, for practical purposes, the cultural resources available on the student's desktop, displacing the sequential curriculum with a cumulative one. That "intelligence," the ability to calculate all manner of expressions, resides in those resources will alter the allocation of effort that traditionally educators have devoted to inculcating such skills, de-emphasizing formal acquirements in favor of intentional achievements. That the system makes it easy to store and retrieve multimedia, as easy as it traditionally has been to store and retrieve printed works, will broaden the forms of representation used in education, reducing the reliance on verbal skills, expanding multi-modal study. These three changes will aggregate into a change of major significance in the cultural politics of curriculum design -- through the era of print, the tight confines of the curriculum have entailed a politics of exclusion, which will now give way to a more expansive, creative politics of inclusion. Let us look at these developments in turn, remembering that in actuality they coexist and function in reciprocal interaction.

Let us begin by noting the effects of networking, which will displace the sequential curriculum with one that is cumulative in character. As we have seen, the logistics of working with printed texts have imposed the sequential property of the existing curriculum. Developmental psychologies delineated the sequences of major stages in the child's growth. But educators should not exag- gerate the degree to which psychological development determines their curricular sequences. That world history should be a tenth-grade subject and American history a eleventh-grade one, or that biology should precede, or follow, physics or geology has little to do with the developmental characteristics of children. It is largely a conventional solution, one among many, arising from the need to divide the curriculum up into discrete subjects that can be pre- sented in some sequence, according to the school calendar. The need for sequence is inherent largely in the constraints of print, not those of psychology. And whether it should be this sequence or that sequence is comparatively an inconsequential question.

What does it mean to move from fifth to sixth grade? A child who does so usually changes teachers and rooms, sometimes even a building, but these are not the essential changes -- the child could move from fifth to sixth grade while staying with the same teacher in the same room. What changes from one grade to the next is the curriculum, and most importantly the set of textbooks the pupils use. Sixth-grade texts differ from fifth-grade texts and so on and as the child progresses through school she does not cumulatively carry the texts from prior grades around. Students in any particular grade find it hard to regain access to the materials studied in prior grades, without somehow going backwards, and they find it even harder to anticipate access to materials slotted for grades higher up. Unable to move easily, back and forth, pupils experience the curriculum as a set of sequential studies. The costs are high. If a pupil did not get one part of the sequence, the omission can be portentous, not because the sequence is the only way things could be reasonably mastered, but because, once missed, the opportunity to make it up may be very hard to regain.

Students will have a very different relation to a computer-based curriculum, assuming that the whole body of culture and knowledge relevant in education has been integrated into a comprehensive system, any element of which they can access at any time from any place in the school. With continuous and ubiquitous availability, the sequence of grades would loose much of its meaning and students would experience study as a cumulative effort. If we think of learning as a causal problem of production, a metaphor of linear sequence, in which one thing leads to another, will seem natural. In this context it is easy to believe that what frequently comes early in the sequence must come there. If we think of learning, however, as an interpretative problem of comprehension, we will generate a different metaphor, one of extended envelopment, with the inquiring mind moving on a broad front, an advance here and another there, until it has confidently occupied the whole field. The sequences by which people come to understand a subject through continuous envelopment are infinite in number and unique to each person.

A smart, computer-based curriculum should be able to sustain an infinite number of paths through it, and it should be able to provide each student with clear reports about what she has so far covered, regardless of the path and sequence she has taken. This learning should not simply produce knowledge, but further elicit comprehension. Educators will develop such a cumulative curriculum as they ask questions such as these:

> » What technological resources will best make all the knowledge, skills, and ideas in the curriculum continuously available to all students at all times?

> » If the subjects of the curriculum become more cumulative, will the mix of activities that are useful to students change, and if so, how?

» Will there be a set of essentials, that must be mastered in a mandatory sequence, with the new system, and if so, how will this component of the curriculum relate to less sequential, less mandatory parts?

» What will happen to distinctions between subject-matter areas if all components of the curriculum are accessible to all students at all times?

» What tools of access, orientation, and expression will be needed by students to sustain their work with such a comprehensive curriculum?

In addition to the shift from a sequential to a cumulative experience of the curriculum, a computer-base for education will shift emphasis from formal elements to intentional contents. "Formal elements" refers to the myriad tasks in which students are required to learn to do things the "right way." Insofar as intelligence can be build into computers, it is this kind of intelligence. They are good at formal operations. They multiply accurately and fast, and they can spell unerringly although they are not good at discerning whether the word they have spelled is indeed the one that conveys the sense the author intended. Computers thus are generally correct but dumb, pedagogically very desirable characteristics, for that can free students to concentrate on being approximate but smart. If students can learn to combine the best of each, they will become both correct and smart, and for this purpose, stress on the intentional contents of the culture will become educationally very important.

Take the example we just introduced, proofreading. Skills of good proofreading with word processors have been radically changing. Not long ago, good technique encouraged proofreaders to disengage entirely from the sense of what they were correcting. One had to look separately at each word and punctuation mark, ideally with one person reading the master copy aloud with the corrector verifying that each word and mark that had been read was correct upon the proof. With a word processor, the allocation of effort becomes significantly different. The computer is an attentive demon at picking up typos and outright errors, but it is a complete boob when it comes to situations where the wrong word appears, a "wither" in place of "either," a "structure" in place of "stricture." To pick up this sort of error the proofreader needs to attend closely to the sense of the text, to treat it as an intentional work the meaning of which should make sense.

As intelligent tools become ubiquitously available to people, the traditional stress in schooling on learning how to perform correct calculations will diminish in importance. But in its place, a premium will attach to the ability to perceive when something that is formally correct is nevertheless wrong because someone made a mistake in entering one or another element in the calculation. To do this, one needs to be, like the new style proofreader, alert to the intentions associated with the matter in question, able to see that the result generated is absurd relative to its controlling purposes. The rising demand that educators concentrate less on inculcating low-level skills and attend more to higher-order thinking skills reflects the importance of this shift, and a good deal of experiment will be needed to discover how to effect it well in the process of making a new educational system.

A third shift will be a function of the use of multimedia, replacing the dominant verbalization of our culture with modes of thought and expression that are more fully multi-modal. For five centuries, written materials have been the main channels of access to culturally significant knowledge. This dominance of written communication arose because printed texts afforded a level of ac- cessibility radically greater than did other modes of cultural ex- pression. Access to printed materials could be general, efficient, and enduring. Access to other forms of cultural embodiment was comparatively restricted, troublesome, and transient.

To grasp this point, consider the theater, the drama, and its place in education. Selecting the drama reminds us that multimedia are not new. Their significance pedagogically may simply be growing of late, however. One often encounters the text of Shakespeare's Hamlet and other great plays as works taught within the curriculum. Producing one or another drama may be a significant extracurricular activity, and teachers will often encourage students to see a professional staging of plays, should such performances be accessible. Nevertheless, the performance, whether produced by students or professionals, has been generally less important educationally than the text of the drama because access to the performance has been highly idiosyncratic and temporary, whereas access to the text has been general and enduring.

In the era of print, written materials have dominated educational effort from the most elementary to the most advanced levels because these have been the materials to which access has been general, efficient, and enduring. Engravings, woodcuts, and other forms of printed images might seem to be a partial exception to this assertion, except that accessing them required one to manipulate the written language, not pictorial images. Thus, to retrieve pictures of Chartres Cathedral, one uses written catalogues and indexes. A radical departure is afoot because now electronic information technologies can provide general, efficient, and enduring access to a much broader range of culturally significant materials: recorded performances of a play can be as easily retrieved as its text, and the retrieval process need not be mediated by words. Explore for a bit why the educational consequences of this development will be vast.

Networked, multimedia systems will provide general, efficient, and enduring access to cultural works of nearly every form conceivable. In the era of print, written works had a cultural usefulness superior to other resources. People could distribute, store, cite, retrieve, and use printed resources far more effectively than they could work with other forms of cultural expression. Essentially, printed materials have long been subject to logical retrieval, whereas other materials have still entailed physical retrieval. A printed work would be distributed in many different locations, and one could refer people to it without knowing the particular physical location of the particular instance of the material that they would consult. Thus one cited editions -- Plato, The Republic, Book IX, 592b -- the numerous instances of which are scattered at many places. One could not reference paintings, plays, sculptures, and buildings, in contrast, in this generalized way -- they exist in unique locations and access to them can require taxing trips, even a pilgrimage. Owing to this superior accessibility, printed materials, usually written materials, have more and more mediated the production and communication of knowledge in modern culture.

Let us sum up this development: in the era of print, verbalization increasingly dominated education. "Verbalization" here refers not only to the spoken word, but even more essentially to the written word and even conceptualizations communicated through the symbolic notations of mathematics and the like. In its most comprehensive form, the basic proposition of verbalization is that higher-order thinking consists in manipulating symbolic notations that have been written down and reproduced through printing.

Slowly through the twentieth century, and building rapidly at its end, other modes of exchanging information, ideas, and knowledge between people are gaining cultural power relative to printed text. For centuries, texts have been available "at any place at any time" -- that has been their power. With the rise of the broadcast media, first speech through radio and then the moving image through television gained part of the power of print, becoming available "at any place," provided one tuned in at the right time. The recording industry gave music full accessibility, independent of particular place and time. Video tape is giving the same accessibility to the moving image, enabling one to view a film at any place at any time, and very soon, with fully interactive multimedia systems, the superior accessibility of text compared to other forms of expression will completely disappear.

When people speak about interactive, multimedia systems, they are speaking about a process by which the full gamut of human expression will integrate into one complex system, with all components, regardless of form, being generally, efficiently, and enduringly accessible. This integration, enhancing the accessibility of all forms of expression, we will call multi-modal, as distinct from verbal. As "verbalization" describes far reaching assumptions about the relation between words and symbolic notations to higher-order thinking, so we here use "multi-modal" expansively to situate reflective thinking in pre-linguistic forms of perception and awareness, which may then be expressed through words and symbolic notations, or through images, sounds and all manner of associations and actions. In this sense, the multi-modal is not a mere opposition to the verbal, not a simple alternative to it, but a Hegelian Aufhebung of it, the upheaval of it into something else in which the original form remains nevertheless included and preserved in the new. The multi-modal in this extended sense thus includes the verbal as one among a number of different forms of reflective thinking: it challenges people to integrate all those forms into a comprehensive and many-sided culture and education. A discernible trend toward multi-modal education is already beginning to take hold with the spreading use of videotapes in schools. This trend will accelerate with computer programs that provide for the multiple representation of important concepts and then with the full-fledged introduction of networked, intelligent, multimedia. Its historic effect will be to broaden effective participation in the culture greatly.

These three shifts -- from the sequential to the cumulative, from the formal to the intentional, and from the verbal to the multi-modal -- will combine to reshape the cultural politics of the curriculum most profoundly. One of the least attractive implementation constraints of the print-based curriculum has been the cultural politics associated with it. The narrow scope of the curriculum has structured this politics, which has been, from the sixteenth century on, highly exclusionist. When the core contents of the curriculum narrow down to a restricted set of materials, dominant groups will use their power to exclude exemplars of competing visions. Humanist schools quickly became pervasively humanist, insisting that all materials in the curriculum pass muster according to standards of good Ciceronian usage. Protestant schools became pervasively Protestant; Catholic schools self-consciously Catholic. And the process continues.

Even as principles of political and cultural toleration have spread, exclusion has remained the controlling principle of curriculum politics. Dissenters have not rallied for inclusion; rather they created their own separate academies. Thus we now have schools representing the interests of many minorities, each with a tight curriculum reflecting the sponsor's parochial preferences. Where minorities have addressed the dominant curriculum, they generally have tried to exclude material they found offensive, keeping pejorative references to themselves out of textbooks or condemning the teaching of threatening ideas. One might expect minority groups to follow a more positive course, to seek inclusion in the curriculum of the most powerfully educative resources associated with their experience and vision, but that rarely happens, for the logistics of the print-based curriculum are simply too constrained. In truth, the print-based curriculum cannot comprise a full, comprehensive selection of the best that has been thought and said, but only an arbitrary subset of it, one defined by a nationality, a religion, a class, a race, or a gender.

For centuries, the necessary narrowness of the curriculum has distorted discussion of the educational value of the cultural tradition. In assessing the worth of its myriad elements, educators must make ludicrous claims that a particular work stands above all others. It is like our great art museums that stash away in vaults vast numbers of important paintings because they have space to hang only a small part of their collections. The case for showing this and storing that is marginal, yet its significance for what the public sees is absolute. The most copious anthologies leave out much more of substantial educative worth than they include. A good sequential curriculum will reflect clear choices and present to students a coherent, authoritative selection because the print- based education functions that way. A new educational system will, however, develop a different way.

A curriculum based on networked, intelligent multimedia will encourage a different cultural politics. It will be greatly more inclusive in scope. Gone will be the finite body of subject matter, which the system holds to be teachable in its entirety and which it therefore authoritatively holds students responsible for learning. The idea that good learning consists in mastering precisely what has been taught will no longer hold. With multi-faceted curricular resources, which can sustain many valid paths of inquiry within them without any inquirer exhausting all their contents and permutations, one cannot specify precisely what has been taught. The computer-based curriculum will comprise far more material, all of it educationally worthwhile, than any individual will master. The process of education will be one in which each student develops his unique selection of it all and the task of his educators will not be to determine exactly what he selects, but to help him extract the fullest education from those elements that he does choose.269 In such a curricular environment, the thrust of cultural politics will be inclusive. Groups will find it hard to compel the exclusion of things they dislike. Instead, their task will be to ensure that the curriculum includes their visions in the most effectively educative form possible. In order to grasp what this task may entail, we need to turn our attention from the question of curriculum contents to the pedagogy that may guide their study. In making a new educational system, the processes of learning may themselves change.

Toward Computer-Based Educational Methods

With the print-based system, education has consisted primarily in imparting an authoritative selection of material to students who are responsible for learning it. True, the print-based school in fact presents to each student much more than he can learn, and the better the school, the more this is the case. Yet the controlling idea of the good student is not that of the wily navigator on the open sea of information and ideas. Rather the controlling idea is that of the student who masters, fully and efficiently, the materials sanctioned by the syllabus, the text, and the test.

With the electronic system, the scope of the authoritative selection of material will jump significantly and the student will no longer be responsible for simply learning it in full. Instead the student becomes responsible for intelligently exploring it and taking from it a unique but sound and useful sampling. Formal learning thus becomes much closer to experiential learning. The student needs to become a skilled explorer, not a docile learner; the teacher becomes, not the master, but the native guide, like Vergil to Dante, interpreting, elucidating, cautioning, exhorting. Good teachers have always worked this way, but they often find themselves in tension with the system when they do. That tension will diminish with the full development of computer-based education. A different pedagogy will be at work.

Working pedagogies are like mutts on the loose -- both gravitate to a mongrel type, mixing traits in a rough and ready way, adapted to its milieu. The pedagogical prescriptions of educational research are like the pedigreed breeds of show dog, strains carefully selected and maintained with extreme vigilance, but quite incapable of self-preservation when loosed at large. To change the mongrel type, it avails little to pursue selective breeding; one must significantly change the milieu. The computer as a system will so change the milieu.

In the current milieu, the pedagogical task starts from an authoritative, finite selection of material that each student is supposed to master. The working pedagogy divides the material into lessons, each with its controlling objectives. The teacher presents the material, trying to engage the students' interest; she explains it, encourages students to practice their mastery of it, and finally tests that mastery through recitation or other means. A computer-based milieu will differ significantly in that it will present to students far more material than they will or can learn, separately or collectively. In that milieu, the current working pedagogies are not particularly useful.

When students confront more material than they can learn, the concept of lesson looses its pertinence. The alternative to the lesson is familiar in the pedagogical literature of this century -- the project. Progressive educators prematurely introduced the project method in a milieu in which it could not thrive. They propounded it for reasons of theoretical preference in an educational milieu that was still unchanged and conducive to a textbook pedagogy. The project method required more extensive intellectual resources than the average school or teacher could command. As soon as the project method went much beyond the laboratory schools, it reverted to the mongrel type. Networked, intelligent multimedia will bring to schools the conditions conducive to the project method. A new system of education will surround each student with extensive intellectual resources, whereupon the project method will come into its own, not as the pedigreed breed of educational researchers, but as the hearty mongrel of the new environment.

Where more is presented than can be learned, the project method will thrive. What are the key features of a project, particularly one that takes place in an unbounded cultural environment? To begin with, a project has a defining task, an energizing challenge, a structuring assignment. This starting point presents certain givens that define the nature and scope of the project. These givens are the ground from which the participants project their activity, forming a plan of work, extending their attention to potential resources, directing their effort outward. All of these matters, to which people tender their exertion, constitute the materials of the project. The materials surround the givens, so to speak, and move out from immediate matters of obvious relevance to items of more and more distant background significance, which, for one or another reason, a participant chooses to include in the field of attention. In addition to these materials, the givens also define relevant tools and resources, processing strategies, characteristic questions, standards controlling inquiry, heuristics for generating hypotheses and interpretative concepts. In a project, the set of relevant tools, while not rigidly fixed, is relatively stable, and participants use these repeatedly upon different materials. The materials, in contrast, are more extensive, bounded really only by the time and effort available and the law of diminishing returns.

Project pedagogy has thus three main components: the charge, the field, and the tools. The charge sets forth what the task will be, and it should do so in a way that is concrete, explicit, unambiguous, and energizing. It also determines who will pursue the project, whether it is an individual or group project, and when it will start and end. The charge also indicates what field will be pertinent and what tools will be relevant, not by circumscribing these but by providing entry ways into them. The field consists of the information and ideas that may be mobilized in carrying out the charge. When we say that the curriculum of the new system will include more materials than students will learn, we indicate that the field of resources relevant to any charge will always comprise more possibilities than a working group can usefully exhaust. The tools consist of intellectual strategies for bringing information and ideas to bear upon a charge. Each discipline consists of materials and techniques and the former constitutes its field and the latter its tools. As much as possible in the new system, the tools of every discipline should be ready at hand for use: mastering the discipline will consist not in learning how to make its tools but in putting them to constructive use.

Consider some examples of charges that might be put to students. Since the curriculum resources to support such inquiry are not yet in place, we do not have working instances to study, but we can imagine possible projects in different fields. Soon, when we can put them to the test of practice, some will prove more effective than others, but for now, their function is not to stand as a list of perfected, or preferred, exemplars, but to exemplify a type with a set of hypothetical instances, some of which may stand the test of practice, others of which will not.

» Students in the upper school Spanish group have as an on- going project developing a multimedia usage guide to contemporary Spanish. They have access to an extensive collection of Spanish and Latin American movies and television programs, recordings by literary figures and interviews with contemporaries describing school life in Buenos Aires, Mexico City, Bogotá, and Toledo. They have on-line grammars and dictionaries, as well as video and audio editing tools. Some students have been working on the project for three years and they manage the whole team. Essentially the team divides itself up to study new material, checking the existing version of the Guide to uncover examples of new usage, or variant usage, and when they find either, the y log them into the Guide, providing examples and relevant geographical and cultural background material. Via the International SchoolNet, students at many other schools make use of the Guide and frequently send in queries, comments, and suggestions. Students working on the project develop a subtle understanding of Spanish usage and a wide appreciation of the cultural contexts of the language.

» Students, aged ten to twelve, work in teams excavating the Timbuktu site, a hypothetical, but carefully designed, computer simulation of ruins from the Ghana, Mali, and Songhai civilizations in West Africa from the eighth to the sixteenth century. The students use a program called Archaeotype, to excavate, describe, record, and interpret several hundred significant objects that they slowly fit together like a puzzle to reveal long-lost civilizations. The site is somewhat oblong, divided into seven sectors, four running west to east on the northern tier and three on the southern. A team of three works on each sector, with one student specializing in dating and chronology, another in tracing cultural influences and patterns, and a third in reconstructing the human ecology and economy. Sometimes all seven teams meet together to discuss the emerging over-all picture of the site, and sometimes the specialists from each team meet to correlate their findings and to discuss explanatory hypotheses. In addition to containing the site and the tools for its excavation, the program they are using provides them with powerful links to the archaeological and historical sources that can help them make sense of what they find. Increasingly as the project goes on, participants realize that they need to develop an extensive historical horizon in order to make sense of the cultural influences of Islam over many centuries that they are finding evidenced and to understand the remarkably far flung trade relations evident in the artifacts.

» Computers will get the word right, but people will need to know that it is the right word, le mot juste. In mathematics, the computational prowess of the computer will devalue human abilities to calculate precisely, but precision is not tantamount to perfection: numbers can be rung up wrong and blundering formulas entered. Sensing that, in various instances, even though the computer gets the answer right, it is not the right answer will be an increasingly important skill. Estimation techniques will become the stuff of ordinary mathematics. As a result, one can imagine among the many ways that skill at estimation might find its way into the curriculum, development in various sectors of the popular culture of the

Reckoning Race, a community contest replacing the old-time Spelling Bee. An extra-curricular group would recruit the school's reckoning racers, the best numerical estimators in each age category. The competition might have three events. First, in the Fast Appraisals, students estimate approximate answers, under intense time constraints, to a sequence of calculations of various types. Second, in the Error Identifications, they track a series of machine calculations, trying to identify which ones, although formally correct, are nevertheless contextually wrong owing to some sort of input error. Third, in the Bug Hunt, they diagnose for a panel of judges the probable cause of the wrong calculations, suggesting steps that might prevent or correct them, and the judges rate the astuteness of their diagnoses. In the emerging computer-assisted culture, reckoning will be a skill all need, and reckoning racers could develop some peer prestige.

» The Poetry Club has become something more than a club. Participants regularly contribute video readings of works composed by them and by their favorite poets. Their friends, and supervising teachers, critique these readings with voice mail, linked to the appropriate places in the video. The Poetry Corner, a conference on the network has a full collection of videos, recordings, and texts on the major poets of the world, living and dead and one afternoon a week a group meets in an assembly room to watch, listen, and discuss. As their graduating presentation, six students work together studying major productions of popular culture from 1950 to 1980, trying to test the hypothesis that during that period composers of music, poetry, and film shifted away from techniques of composition conditioned by the processes of writing, reverting to those associated with oral-epic performance. In three months they will present to the school a booming multimedia documentary on their findings and they are asking a Public Broadcasting Corporation scout to come, hoping she will want it for their national cable list.

» A group of middle and upper school science students have as a project, conducted with several teachers specializing in different aspects of science, an inquiry into the relationship between observation and theory in the development of science. How do scientific instruments shape scientific knowledge? In the historical development of the sciences, how have limitations on the capacity to take and record observations of different kinds of phenomena influenced theoretical explanations of those phenomena? The project team works with simulated instruments and communication resources characteristic of different historical settings in the development of science. They assemble typical observations pertinent to a problem and research the historical theories explaining solutions to it. They brainstorm about alternative theories that might be based on the observations they can assemble and write up these theories in scientific papers that they submit via network to the Academy of Simulated Science, which includes interested adults and other such groups at other schools. They criticize the contributions, usually showing that the proposed theories would not really have been possible given the state of observation and understanding that then prevailed, but occasionally an alternative stands up to the criticism, revealing a possible path of theoretical development in the history of science and technology that might have been taken but was not. Students engaged in this project develop a keen appreciation of the difficulties in carrying out scientific inquiry, as well as extensive knowledge about key scientific problems and the strategies used to solve them.

» Students eight to twelve years-old take part in the Children in World Art Project. The younger ones start by picking several periods and cultures and browsing through the included images of children, working on a presentation explaining their sense of what childhood would have been like in those times and places. Doing this, they begin to research the geographical and historical contexts and start to learn how to empathize with their subjects and to use contextual information to check and test their understandings. The older children help the younger and evaluate the set of images for redundancy and gaps, developing an acquisition search list that they can circulate to curators of museums and collections that may have the sorts of images they want. The project participants use the International SchoolNet to find historical documents that help inform an understanding of the experience depicted in the images. In addition to extracting the representational information about childhood that the images contain, the children will need to respond aesthetically and emotionally to the images, interpreting with them something about the subjective, qualitative experiences that they reveal.

» As satellite based telescopes become more numerous, powerful, and diverse, a tremendous problem of logging all the information sent back will develop. As a solution to that, scientists initiate the National School Space Mapping Project. Each school recruits several teams of three students each to receive and assess data. The scientists overseeing the project assign to each team a small, specific quadrant of the surrounding universe. As data comes back from its diverse sources into various repositories, the International SchoolNet routes all data pertaining to a quadrant to the team that handles it. Each team collects and monitors the data it receives and maintains a full descriptive and explanatory catalogue of what appears in the observations in its quadrant. To do this the teams need to understand the various sorts of telescopic observation techniques and how to apply standard astronomical and astrophysical theory to the astral population of their quadrant. Should a team receive new observations that do not fit within the standard theories, the team will need immediately to alert its supervising scientist. The participating students will learn a great deal about the content and practice of astronomy and they will help absorb into it the wealth of new data that is beginning to flood back to earth.

With such projects, the teacher's role will be to oversee, to manage, and to facilitate inquiry. To start, she will need to mobilize the resources of the profession to set the charge and put it to her students. Defining the mandate for her students will be much like planning a course, although the particulars will differ somewhat. It will begin by selecting a set of particulars that will put a significant intellectual problem to students. This intellectual problem should be such that students will acquire knowledge, skill, and understanding by working to solve it. The problem needs to be put in such a way that students can grasp it and work on it productively. For that to happen, the teacher must ensure that the field within which she has situated the charge has in it a genuinely open-ended range of resources that students can use effectively to fulfill the charge. Likewise, the tools at hand for working on the problem need to be appropriate, usable, and effective. A fascinating charge situated in a rich field without good tools will not lead to an effective project, for students will find themselves unable to exploit the materials before them. Similarly, a good charge and powerful tools deployed in a deficient field will not sustain interest or development. Finally, despite a well-stocked field and first-class intellectual tools, students given a weak charge, one that does not put an energizing, orienting problem to them, will not do much with either the field or their tools.

Some may object that a computer-based project method such as this seems more like the methods used at advanced university levels than something appropriate for elementary and secondary school. The observation would be correct; the inference that this shift would be ill advised may nevertheless be unsound. In many ways, basing education on advanced information technologies will move strategies of college and graduate education down to lower levels. The intellectual context of advanced instruction is not the textbook, but the library and the laboratory, which in the era of print have cost a great deal to assemble and to avail to students. The basic pedagogy challenges advanced students to inquire into the sources of information and ideas through study and experiment and then express their results to a public of peers. Learning occurs in three key activities -- putting the question that generates the inquiry, selecting and evaluating materials potentially relevant to it, and expressing results in ways that others will find clear. Young children can perform these activities. Project methods at their best will transfer this pedagogy for use with less advanced students working on more foundational areas of inquiry.

Why has a project pedagogy been primarily restricted to advanced students? Again, the answer to this question lies, not in the nature of learning, but in the implementation constraints of the print-based system. Does the long selective ascent to graduate school winnow from the many those few who can uniquely learn from open-ended inquiry in a well-stocked library? Well-stocked libraries and well-equipped labs are very costly, and they have low carrying capacities in the sense that only a few can use them at any time lest their usefulness be destroyed. While one person uses a text or lab instrument, others cannot. If, for instance, the scholar working in an academic library too often finds that the text he needs now is in use by someone else, he will find his inquiry slowed significantly and will quickly declare the collection unfit for serious use. Academics restrict access to advanced intellectual tools, not to ensure that someone does not waste his time trying to use tools he cannot productively employ, but rather to ensure that the tools will be in a productive state for those few granted access to them. We very reasonably do not fill the stacks of research libraries with hordes of fifth graders, not because the fifth graders could not learn in the process, but because a rare resource of advanced scholarship would lose its usefulness for that purpose.

Access to information and ideas encoded in digital form will have different constraints from that of print. Provided the networks leading to them have sufficient carrying capacity -- and they soon will -- open access to source collections will not diminish their usefulness for serious scholars. Whoever uses an electronic text uses an ad hoc copy, and it does not matter how many ad hoc copies are in use. All sorts of materials can go to all sorts of users without devaluing the intellectual effectiveness of the work. Climate readings from stations round the world will go simultaneously to the Lamont Geophysical Laboratory and Miss Jones' fourth grade class at PS92 in Harlem and wherever else someone curious about the readings may be. Project pedagogy often failed in the past because students did not have access to the resources needed to inquire effectively into the questions posed to them. That is one of the great limiting factors on human inquiry, whether conducted by the young in their efforts to appropriate their culture or by the expert in their attempts to advance it. Ptolemy got it all wrong, not because he was dumb, but because the observations he could study were too few and too imprecise. Access to information and ideas is opening astoundingly and educators at every level will need to adapt their strategies to the project method to make use of it.

A second reason the project method often failed was that younger students lacked suitable means of expression to carry their inquiry through to some conclusion. The cartoon stereotype of naked children wiggling around the progressive schoolroom, imitating sperm in search of the ovum, reduced the problem to an absurdity. Without adequate tools of expression, inquiry-based learning culminates in an inarticulate collapse. The digitization of our culture, however, provides greater access, not only to information and ideas, but to tools of expression as well. This process is evident with what young children can do with word processors and desktop publishing systems, but that is simply the leading edge of what is in store. Design tools, graphics tools, video production and post-production tools, analytical tools of the most sophisticated sorts, all will be ordinary resources of ordinary schools. Educators will need to adapt their strategies to make use of these as well.

Furthermore, a significant shift of advanced pedagogies to more elementary levels is not unprecedented in historical experience. In the educational transformation of the sixteenth century, the pedagogical activity of the universities shifted downward to the schools much in the way here envisioned. Prior to print, studying subjects for their meaning and significance was the work of the university. Having learned through an arduous preparation to make a dependable written text on hearing it read aloud, the advanced student could then turn to reading and absorbing its significance. The work leading up to that ensured that a student could, hearing complex ideas read aloud in Latin, transcribe them accurately. With that skill acquired, the student could then hear Aristotle, make the text, and discuss its interpretation with others. With print, Aristotle and many other authorities became available in inexpensive editions. Making the text ceased to be the aim of preparatory education; as a result, reading and interpreting the text became a major activity much earlier in the educational process than it had previously been. That, precisely, was the agenda of the newly invented Gymnasium.

Of course, in the sixteenth century, many reasonable people doubted that the substantive study of authority could be done by younger students, for experience had shown that it was the proper concern only of advanced students. For instance, the University of Basel took offense at the curriculum of Thomas Platter's school, because it included the interpretation of texts usually reserved to the university. Over several years the academic authorities maneuvered to require Platter to bring his students to the University for public examination, expecting to prove that his students did not understand the subtleties of the texts he recklessly assigned. When the examinations took place, Platter's students showed a robust comprehension and the University had to accept the idea that younger students could usefully study substantive content. In like manner, as a new system of education emerges, pedagogical concerns hitherto associated with advanced study will become increasingly important throughout earlier stages. This will have deep implications for the profession of teaching.

Improving the Conditions of Teaching

Teaching in the print-based system has required skilled professionals. The earliest Protestant theorists of schooling pointed to the importance of well-trained teachers, if the system were to be effective. And the need has been constant since then. Nevertheless, the conditions of educational work within the print- based system have had significant deficiencies. Teaching a set curriculum with set texts tends to be highly repetitive, year to year, and teachers often find their work routinized. They cannot do much beyond the text and after a few times through, the text be- comes a familiar locale that ceases to challenge their imaginations. This is the basic process of routinization, too often evident in the career of teaching.

Allied to routinization is deskilling, which is a kind of routinization that happens, not as a by-product, but as the purposeful result of policy. When work requires higher levels of skill than the average worker may possess, managers have often tried to simplify the job, believing simplification to be a more economical way to match job with skill than it would be to improve the skills of the worker. Complex tasks once performed somewhat unpredictably by high-paid skilled artisans were analyzed into component steps that anyone, following instructions, could passably perform. Unskilled workers replaced the artisans with the process tightly managed according to the principles of Frederick Winslow Taylor, and the output became predictable and the pro- duction costs minimal. Curriculum developers have sometimes used these techniques to seek a "teacher-proof" curriculum, hoping thereby to better guarantee results and to get by with lower pay for less-skilled teachers. In many industrial walks, such processes have reduced numerous artisans to mere machine-tenders, mindlessly repeating dumb tasks as products wend toward completion along the line.

An industrial system that achieves production efficiencies by steadily lowering the skill requirements in many forms of work over several generations can find itself in trouble should the skill requirements of work suddenly increase. Advanced technologies in the work place have caused precisely this shift in recent decades. In factory and office, deskilling jobs had made much work diseducative. And educational preparation for work in such jobs put a premium on rote learning and routinized teaching in the "factory school" where students were primarily acculturated through drill and practice to follow instructions with uncomprehending accuracy.

Increasingly, high technology reverses the polarity on the skill needs of labor in the industrial and service sectors. Machine- tending jobs, performing a single task according to a prescribed manner in a complex division of labor, are growing scarcer. Process-managing work, controlling a complex system by monitoring information about the condition of its parts, has become more prevalent. In them, a mindless mistake can prove most costly. This shift in polarity carries all the way through the educa- tional enterprise. Learning to learn and critical thinking are fast becoming important educational results, not only for the most successful, but for all who go through the system. In such a situation, the demand arises for more highly skilled, fully engaged teachers. Hence it is becoming socially important, not to simplify instruction so that any teacher, no matter how unskilled, can make it work provided he follows instructions, but to structure it so that the teacher will continually develop his skills, growing more and more adept with more and more experience.

As heuristic guides, nurturing the work of inquiry groups, using powerful intellectual tools in complex fields of information, the challenges on teachers will be great. It is tempting to object that the ordinary teachers will not be well-prepared to perform this role. The span of pedagogical possibility is not fixed forever for teachers, any more than it is for students. How a teacher develops over the course of her career, managing teams of students working with advanced tools of scholarship in open-ended fields of inquiry, may be very different from the way she develops instructing five classes of eighth-graders, year after year, in a set survey of ancient history. The pedagogical shift making advanced methods appropriate at earlier levels will affect teachers as well, making the content of their work more like that of the college professor. Not only will the educative effects of the work itself be different, but with that change, people attracted by the work to the career may alter in ways currently difficult to predict. For better or for worse, work shapes the worker far more than the worker shapes the work. If a new system of education becomes structurally possible, teachers will adapt to its conditions, which, fortuitously, seem expansive and humane.

Changes in these areas -- in the organization of time and space, in motivational strategies, in the presentation of the culture, in the pedagogies guiding its study, and in the character of the teaching profession -- will arise, not as a causal sequence, but as a set of reciprocal interactions. The secret of historical initiative, of voluntary action, lies in this reciprocity -- we can initiate change anywhere within it and once started the changes will propagate interactively around the system. Nevertheless, one needs some sort of starting point, a way to begin. What might be a good way to initiate changes that can reciprocally reinforce themselves and spread through the system, transforming it all around?298 Consider as a possibility the potentials of computer networking. Networks are essential components of the computer as a system. They are developing rapidly in power; they are proliferating, squirming wires quickly wrapping the globe in a pulsing mesh of messages. Telephones, television, and computers are fusing together in ways that can pervade the schools and provoke key changes in them. Advanced networks can trigger changes in the environment, motivation, cultural organization, educational method, and the teaching profession in ways that will reciprocally propagate.

Let's look briefly at how networks can influence each of these areas. No one domain will come first; rather they will all come at once, each reinforcing the others.

» If the entire school plant of the nation had to be rebuilt in order to accommodate alternative groupings in time and space, thorough-going change would be impossible. But networks will make possible the "virtual rebuilding" of everyday schools. Networks will enable computer-based work groups to function well without being together in space and time. Sub-groups in different classrooms will link together electronically and function as a unit. E-mail, voice-mail, and video-mail will give a measure of interpersonal immediacy to the collaboration. Current structures that seem to rigidly impose set routines will become sites of great flexibility, if effectively networked.

» Networks will greatly facilitate collaborative activities among students working on projects. Asynchronous communication improves the ability of people to work together without loosing their autonomy. Networks further ease the sharing and managing of common information and ideas. Students can manage the logistics of cooperation more effectively and networks will help them work together to interpret mutual results.

» Networking is, of course, fundamental in achieving the curricular condition where all cultural contents and pedagogical resources are accessible to all students and all teachers all the time. Networking, however, is not only a necessary condition for bringing this condition about; it may more interestingly be a sufficient condition -- in a well- networked school, all academic resources will be available to all at all times unless authorities impose access restrictions to prevent it. Thus, should powerful networks proliferate into schools, very probably the information base for the cumulative curriculum will be in place, whether or not the managers of those schools intended to construct it.

» Intensive networking of schools will encourage a shift in educational strategy towards the project method. One can imagine using a network as an infrastructure for group recitation, and there will surely be times when such uses of it will be important and valuable. But networks are switching systems that do not particularly conduce to actions in unison, but rather facilitate branching out and linking by people who are doing different things while working together on a shared project. Powerful networks that give lots of people access to lots of resources will sprout projects spontaneously -- interest groups on this and that -- and educators will scamper to capitalize on these spontaneous energies by shifting instructional emphasis more and more to a project method.

» Networking, in and between schools, will also shift the professional ethos in teaching away from routinization. Teaching is now rarely a highly collegial profession because the structure of the curriculum and the classroom tend to seal teachers off from intensive interaction with their peers. Networks will help teachers collaborate with each other, within the on-going flow of daily activity, much more than they do now, to pool classes, to share problems and techniques, to develop special competencies and interests, and to refer students with specific needs and concerns to each other for help. Networks will allow teachers to work together through the walls of their separate classrooms and across the periods of their schedule.

In these ways, introducing powerful networks, and all the associated computing resources that might come with them, can forcefully prod the system to change. But can the polity rouse itself to initiate such investments? To what degree would the public sustain the costs of such efforts? We turn, thus, to our concluding question, what civic agenda for education will best actualize the pedagogical potentials of digital technologies?

Chapter Six - Education and the Civic Agenda

Computer-based schools and the cumulative curriculum will cost money. In order to construct a technology-based educational system, the level and structure of educational expenditures must change. Let us estimate some numbers.

Currently, kindergarten through twelfth grade, spending for instructional materials per pupil amounts to a small fraction of the total. Most goes instead for salaries of teachers and staff. With a heavy infusion of technology, educational costs for salaries, plant, and the like will probably not decline. Assume that technology makes it possible to have fewer teachers, a questionable assumption: the level of the teachers' average salary would likely rise proportionately, keeping labor-related costs even. Hence to implement a technology-based educational system, we should expect total per-pupil costs to increase significantly, with a big rise in spending for instructional materials and equipment. "Other expenditures for instruction," a mix of many things, now amount to a bit over 9 percent of expenditures per pupil, and of these, about 2.5 percent, on average less than $100 per pupil per year, go for instructional supplies such as textbooks, library books, and instructional resources.

Assume that special investments saturate the schools with technology. This saturation will require a computer notepad for each student with wireless network link; a high-function workstation for every four students; a substantial infrastructure of servers, networking, teachers workstations, and special displays; and a significant complement of software and digitized contents. We cannot predict exactly what these will cost as the technology matures. Costs of $2,000 in each of the four categories, amounting to a per-pupil technology investment of $8,000, would probably be high. Costs of $750 in each, a total of $3,000, would probably be low. Accountants will treat this investment as property with a five-year useful life. For parts of the investment, the actual life might be shorter, owing both to intensity of use and rapidity of obsolescence. The upshot is an annual, per-pupil technology cost between $600 and $2,500, most likely, let us guess, around $1,250, which, when added to current expenditures, would increase per pupil costs about one-quarter over current levels. This increase is sufficiently large to require a compelling public justification.

Having to develop powerful justifications for substantial increases in educational expenditures is not a novel challenge. Universal, compulsory school systems evolved as nations found reason to devote increasing percentages of their GNP's to such costly instructional efforts. Over the past five hundred years, educating the person and the public has never become more efficient, providing equivalent or increased output for substantially less input. Rather it has become more important, more valued, with parents and polities deciding that increased educational results are worth increased costs. Great educational activists like Horace Mann and Henry Barnard proceeded by developing a civic consensus to increase the level of educational expenditure and effort. In precisely this way, policy justifications for a computer- based educational system will need to convince the public that the increased costs bring benefits that justify the added expenditures.

To justify increased educational effort we need to arouse passion and commitment; we need a will to believe. Prissy pundits find it easy, retrospectively, to disclose the interplay of self-interest within transforming movements, but prissy pundits rarely work change in their own world. To build the existing educational system, many people had to act counter to their narrowest self- interests. Educational reformers needed both stratagems to rationalize participation along with visions to inspire it. In building a new educational system, we cannot demand purity of purpose, but we must call for greatness of vision, for the changes needed will entail far more than simple readjustments of existing efforts. To institute a new system of education, educators will need to marshal large arguments of broad public purpose. To do that, leaders will need to excite pedagogical passion, to articulate an educational vision, to risk failure for the sake of a novel, untested, yet moving future, for an educative polity.

To change the pedagogical world, educators need both material agency and humane vision, both power and pedagogy. To change the world, people need reasons to take risks, to incur resistance and hazard failure. They need forceful agencies with which to stake success, to grasp the opportunities for action that their vision avails them. New agencies will be at hand with the development of computer-based education. To what degree can we provide ourselves with the historic vision that will enable us to put this power to worthwhile use? What reasons do we have for taking the educational risks inherent in the pursuit of fundamental change? As Poor Richard said, "would you persuade, speak of interest, not of reason." In looking for these reasons, let us speak first to interests, then we can turn second to established civic goals and third to novel aspirations.

In diverse ways increased educational expenditures can bring substantial offsetting benefits. Broadly speaking these benefits are of two kinds. One consists of improvements in well-being that result from educational success. Throughout the population, a better education translates, to some degree, into increased productivity and a greater ability, personal and public, to capitalize on opportunities for bettering the quality of life. The other kind of benefit consists of savings accrued by reducing the mounting costs, public and private, that result from educational failure. Costs of crime, unemployment, even aspects of health may be considered, to some degree, as costs incurred because the educations many receive are insufficient to prepare them to deal with the world they inhabit. Less educational failure would lower the cost of coping with calamities. Let us look at the costs of failure more closely, and then return to the improvements that educational success can bring.

Resist at the outset the parsimonious effort to put the whole burden of social policy on educational reform. Much educational failure is not a failure of education. Many problems in schools are not problems of schools. Hungry children, the tired, the sick, the brutalized, the frightened, the homeless: they will not succeed, on average, in any school. Despairing, disillusioned youths, whether rich or poor, will see no reason to develop their abilities. Without real leadership and without social policies that address the extra- curricular causes of educational failure, large-scale educational reform can be a cruel hoax for the disadvantaged. The schools fail them, first, for reasons that are extrinsic to education and improving the educational efforts, without addressing the extrinsic problems, will benefit the disadvantaged little. In effect, educational reform without strong social policies will improve institutions that work best for the children of the middle and upper classes, while leaving in place a system of causalities that make the schools work poorly for the poor.

Resist likewise, however, the short-sighted effort to put the whole burden of educational reform on social policy. Much educational failure is a failure of education, and many problems in schools are indeed problems of schools. Intensive use of educational technology can make schools more effective for all and more effective especially for those currently floundering in our print-based educational system. If we are serious about social betterment through education, we will not finance educational reform by diverting into education expenditures needed for other social services.

Assuming decent policies in those other social services and effective school reform, however, reducing the failure and insufficiency of education could eventually lead to significant cost savings to society. Jail is expensive. Welfare dependency costs a substantial amount and it withdraws talent and energy from the work place. Long-term joblessness keeps the economy in a state of under-employment and may slacken incentives to innovation. If, over decades, the frequency of failure and under-achievement in the educational system can be diminished significantly, then it would be reasonable to expect these large social costs to be substantially less than they would otherwise be.

Likewise, positive benefits from improved education would arise over the long-term as better performance affects relative national advantage and fundamental economic prospects. In the late 1950s the pursuit of relative national advantage through education resulted in the National Defense Education Act. Now the quest for military preparedness is giving way to the problems of remaining competitive in a global economy. A fully developed computer- based educational system can have three types of significant effect on the over-all competitiveness of the American productive enterprise.

> » First, insofar as the computer-based system is substantially more effective than the print-based system, the general level of American preparation for productive effort within a knowledge-based economy will rise. » Second, insofar as the economy itself is increasingly a computer-based system, a computer-based educational experience would align more effectively with the skills needed in the job market than a print-based experience would, even if the absolute level of attainments through the former were not significantly better than they are through

> the latter. At least the student would be acculturated to the significant tools needed in the work place. » Third, insofar as the organization of work in advanced sectors of the economy places a greater premium on persons' abilities to function cooperatively in groups, a computer-based educa- tional system that substantially extended opportunities for co- operative learning would better prepare students for working together in ways that the economy needed than the competition-prone print-based system would. We can hypothesize that all these benefits would develop with a shift to an intensive use of information technologies in education. Their aggregate effects could be considerable on the economic well-being of persons and the public.

It would be premature, however, to estimate from current experience how the educational transformation would increase production and save on social costs, or to attach precise dollar benefits to them. Large-scale structural changes in education will take ten to twenty years to develop and introduce. Their benefits will accrue over the ensuing decades, becoming fully evident only in the mid-twenty-first century. It is like planting oak trees -- our children and their children will be the beneficiaries. Is it worthwhile to take expensive initiatives, when their outcome will long be uncertain?

Consider the wager. If substantial improvements in education can be wrought, their long-term future benefits will be great. If they cannot be achieved, the long-term future consequences may be serious, driving a wedge of inequality deeper and deeper into society, separating those that the educational system benefits further and further from those that it fails. The opportunity to improve education through investment in digital technology is quite new. Conditions are ripe for reaping a high payoff. Since no society presently spends much for educational technology, added investment in it is unlikely to encounter the law of diminishing returns for a significant time. Hence, spending on educational technology would seem to be the reasonable bet for substantially improving education, but to take the risk out of the calculation, to convert the bet into a certain benefit, would require that we claim more than we can presently justify.

When all is said and done, rational calculations of advantage associated with major innovations are wagers, fraught with unknowns. Retrospectively, the highly successful innovations seem to have been sure things, but prospectively they were not. Entrepreneurial and technological vision consists in acting wisely yet decisively in the face of uncertainty. Why take the risk? In this case, the risk may be worth taking for multiple reasons. Chances are good that indeed the practical consequences of the effort will be highly beneficial. Additionally, the social and human effects of the changes may be both significant and desirable. We turn to the second set of reasons justifying the risks of innovation: intensive use of technology in education may lead toward fulfillment of established civic goals.

Although the agenda of freedom has taken great strides in recent history, that of equality has not. Each year during the 1980s the percentage of Americans living below the poverty level was higher than in any year during the 1970s. Significant portions of the population are addicted, nearly unemployable. Uncounted families cling to survival -- homeless people hawking Street News, begging, and scamming, and groveling through the refuse of the middle class for cans and bottles redeemable for a nickel each. Many, prideful on having made it, blame social failure on the failings of those who suffer the failure, and espouse social policies designed primarily to help those already adept at helping them- selves. In our willingness to bail out bankers who mismanaged the savings of the middle class while we cut back on programs to serve those most in need, we poorly represent the centuries of humanitarian progressivism that has animated our traditions. Pascal put it well: "we do not display greatness by going to one extreme, but in touching both at once, and filling all the intervening space." Freedom without equality does not sum to greatness: the agenda of equality requires renewed civic effort.

Educationally the agenda of equality appear in the prevalence of drugs, dropping-out, and the difficulty of making schools work in areas of chronic urban and rural poverty. These are big problems and they will require complex solutions. Substantial issues of distributive justice complicate these problems, but they do not inhere simply in the unjust allocation of resources. Pedagogically, the problem is one of recognition, a feeling of control over one's own education. Regardless of race, class, gender, religion, or ethnicity, each child should have an equal opportunity to participate in a school that he perceives as an institution that has been designed specifically for him, that serves him, that is his own. If the school appears as a hostile power to the youth, he will see it, not as a resource, but as a threat to be neutralized. School choice may help diminish the prevalence of this situation, but choice between schools may not be as significant as engaging options within schools. Those who feel school now to be alien influences may simply use school choice as a new opportunity to neutralize the threat.

Unfortunately, the current system of schooling is part of the cycle of causality, not a means of breaking it. Interpreters of the education system tend to be people who have done well within it. They experienced schooling as a happy system for self-development and self-advancement. Interpreters often therefore have difficulty seeing how the experience of the less successful was fundamentally different: for many others, the same system functions as a powerful social sorting mechanism, frustrating their self-development and reinforcing their disempowered status. They experience schooling as a system by which the society at large, even they themselves, legitimate their impoverished prospects. Choosing the "wrong" school will continue to work this way. To counter the causalities of inequality, choice is essential in education, but within schools, not between them. A computer- based system of education may help break the cycles holding the truly disempowered in thrall by creating three forms of significant choice within schools, which they and everyone else, can use to good advantage.

First, the way the current system handles subject-matter is invidious. Size constraints on textbooks require that a very limited selection of ideas and information be packaged together. The materials chosen become, ipso facto, sanctioned by inclusion in the standard texts and tests. The result will harmonize with the experience of some children and be at odds with that of others; some will find more with which they can identify emotionally, and others less. Interest groups realize that what the selection includes and excludes has import, good and bad, for their interests. However, since textbooks have a seriously limited scope, the politics of text development has been a contest to exclude any particulars that may offend some articulate sensibility. Increasingly, such efforts to exclude all possible cultural bias tend simply to render the curriculum pedagogically impotent for all.

In contrast, computer-based curricula can be comprehensive and inclusive. The politics of a computer-based system has the possibility of opening the narrow confines of the standard curricu- lum to genuine multicultural possibilities. With the new system, the politics of curricular development will cease to be exclusionary, be- coming instead a many-sided effort to ensure that what may empower this or that interest finds its place within the spacious system. In a computer-based system, diverse racial and ethnic groups should join to develop multicultural curricula through which high levels of disciplinary mastery can be achieved along numerous paths of interest and inspiration.

Second, reliance on printed sources in the current educational system provides a narrow access-path to the power of knowledge. Those who experience the existing system as disabling do not do well with book learning. To be sure, in theory the system offers them vocational tracks, which put greater stress on learning to make productive use of hand and body. But these tracks have a stigma associated with them because everyone knows that in a print-based culture the only real access to knowledge is through verbal facility: no matter how manually skilled one becomes without high levels of verbal knowledge one will be held mentally second- rate. Insofar as a computer-based system can complement the verbalization of print media with the multi-modal powers of electronic media, multiple access paths for acquiring and manifesting mental excellence will open. This will not do away with distinctions between people with respect to intelligence and intellect, but it can broaden the existing structure of intellectual opportunity.

Third, the way the existing system motivates educational effort through pervasive competition creates a sorting mechanism that deprives disempowered groups of their more able members. Those who succeed in the competitive assent often assimilate to the dominant elites. Imagine an educational system that did a better job at fully developing the potentialities of each person while less effectively grouping and sorting the members of age-cohorts according to their performance on a narrow set of mandarin acquirements. Such a system would be a very different response to the Jeffersonian idea that talents distribute randomly through a population. Rather than co-opting those talents to the service of power and privilege, it would preserve those talents in their random distribution, leavening the whole through a multiplicity of communal excellences. By putting a premium on cooperative learning and by offering a multicultural curriculum with many paths to mastery within it, a computer-based educational system can function in this more genuinely Jeffersonian manner.

Here, we should shift attention from established civic goals to the third set of reasons for incurring educational risks, those concerning novel aspirations. Truly significant change in education may have the potential to redefine the polity itself. If the computer as a system constitutes a fundamental shift in cultural communication, then we should expect concomitantly a significant re-definition of controlling purposes. Values have an historical relativity, without becoming arbitrary and meaningless, without being "relativistic" in the pejorative sense. At any time and place, the given historic context is mandatory, and it entails the importance and validity of some values and the irrelevance and wrongness of others. But across time and place, the given historic contexts change, and with those changes there follow changes in the values that compel allegiance. Politics in a digitized culture may differ in significant ways from the politics in a print culture. As Aristotle observed, "the end of the state is not mere life; it is, rather, a good quality of life." As the contexts change and we come to inhabit a fully digitized culture, we may find ourselves obliged to define "a good quality of life" differently than we did before.

Soon the ethos of "More!" must give way to an ethic of "Enough." As that happens, problems of public purpose will remain, but they will undergo revaluations. In the era of print, those justifying the support of education have contended that schooling is a useful, efficient means for achieving publicly sanctioned ends. For the past few centuries, those publicly sanctioned ends have often been variations on "More!" -- more power, more wealth, more influence, more adherents, more law and order, more consumption, more garbage too. What good did the print-based system serve as it mobilized competitive energies, distributed broadly a level of literate skills through the population, and sorted the young effectively according to the quality of their performance within the system? It served best as a means in the pursuit of "More!" It energized expansion and legitimated the allocation of less to those who fared poorly in the schools. Would the print-based system serve well in support of an ethic of "Enough"? A system that relied on cooperative learning, one that could attract participation in educational self-development, not as a means but as an end itself, one that enhanced a student's quality of life, her bonds with others, her shared experiences of personal meaning, would be an education well adapted to the ethic of "Enough."

A competitive ethos of "More!" can take hold among people when they feel they can safely compete for possession of finite, limited goods. Where the competitors become aware that the competition is fundamentally unsafe and unstable they withdraw from the unbridled continuation of it. In the late twentieth century, the age-long competitions for national advantage, pursued through the pursuit of more population, more armaments, more material output, has become increasingly unsafe and unstable as armaments become too destructive to use, populations too large to feed and nurture, and material output exhausts natural resources and threatens to destabilize world climates and ecologies. A thoroughly cooperative education can lead to a thoroughly cooperative society in which people realize that a good quality of life depends, not on standing higher in the hierarchy of advantages, but on all joining together to realize their common potentials. It leads to an ethos, not of comparative advantage, but of mutual support.

Unlike the various forms of advantage, which are finite and relative, education is not a limited good. More education for one need not mean less for another. This unlimited quality will especially characterize education in a computer-based system, for the dynamics of digitization allow unlimited instances of works and resources without diminishing the originals. In such a situation, education can be a public purpose, one pursued by each and all, without provoking a limiting competition, without one person being pitted against the other. Taken as a means to relative advantage, people have an interest in acquiring learning and withholding it from others. But taken as an end in itself, a controlling definition of "a good quality of life," education gives people an unbound mutual interest -- the educational attainments of others enrich the educa- tional possibilities that I enjoy.

An educative polity will be a polity adapted to a world of finite material resources. An educative polity will be one with infinite spiritual resources, one in which the unlimited potentialities of the human spirit provide the endless frontier. As Heraclitus said long ago, "You could not in your going find the ends of the soul, though you traveled the whole way; so deep is its Logos!"

A computer-based educational system is not the only possible basis for an educative polity, but insofar as it can supplant competitive educational motivations with cooperative ones, and insofar as it can genuinely broaden educational opportunity by opening multiple channels to knowledge, it will facilitate the emergence of one. The computer as a system will make all educative resources available to all people at all times, and it will greatly expand the scope and substance of those materials. In those conditions, education ceases to be mere a means to extrinsic ends and becomes an end itself. With those conditions, power and pedagogy may join to redefine political purpose, making education its central aim, the object of the good life. The stakes are worth the risk.

Appendix - Device Indepenedent Referencing

Interactivity is the ballyhoo of hypertext. Its theorists decry the linearity of the printed book. They do so thoughtlessly, and thereby miss both the problem and the opportunity. Books are highly interactive tools. Moreover, as interactive tools they are even very efficient. Despite this interactiveness characteristic of books, many printed texts are "linear," meaning they have a beginning, middle, and end. This sequentiality, which writers carefully compose and readers usually follow in a full reading, is an attribute of the text, not the book. The reason many texts are linear has nothing to do with the technology of print.

A book as a technological artifact is highly interactive and non- linear. Grab one and you can flop it open in the middle, skip around, and thumb through its pages forwards or backwards. You can consult it in all sorts of odd sequences and quite often you do. With the index, a 500 year-old tool, you can hop around from topic to topic, nearly instantaneously. Publishers have long designed dictionaries, directories, and encyclopedias specifically for non- linear access, and reference books work well. Our fingers quite naturally apply enhanced binary-search algorithms on such volumes as we look an entry up. Books have little in their structure that is inherently linear.

Why then do we decry, with a seeming plausibility, the linearity of books? The answer is simple -- the text in most books is linear because writers and readers have chosen linear presentation, over the years, despite technical freedom to do otherwise. Proponents of hypertext should pay close attention to this fact. Encyclopedias are interactive documents. Writers craft entries for them assuming no continuity with what lies before and after. They include numerous cross references, links in the jargon of hypermedia. They are most useful works, but rarely do they hold us spell-bound by the suspense of the tale or the force of the argument. Good writing of many types is linear, not by technological necessity, but by the nature of the discourse.

Interactivity is not the special purview of text on-line. Linearity is not the curse of printed text. All books, as such, are interactive; some texts are interactive, when people specially design them for that purpose. Technological constraints do not determine the interactivity of such texts. No book is inherently linear, unless one were to trace the book back to its predecessor the scroll, and readers could even work scrolls interactively, back and forth. Many texts are linear because writers make them so, linking each paragraph to its predecessor with lineaments of artful diction, logic, and narrative tension. Thus, as with interactive texts, technological limitations do not cause texts to be linear. Quite the contrary, their linearity is a triumph of linguistic artifice over technologic artifact.

Such reflections suggest that we should rethink the hype about hypertext. If text on-line is to develop and flourish, it will probably recapitulate many virtues of printed text, especially those that writers and readers have imbued in text despite technological invitations to shape the work differently. One of those virtues is intelligible sequence, narrative form, compelling argument.

This virtue pertains, not only to text, but to other media as well. Most examples of video-oriented hypermedia seem sophomoric for they consist of brief, flashy clips, designed apart to stand alone. The emotional power of media lies largely in their cumulative effects, built sequentially over time. To randomize the shots of a great film dissolves it into meaningless sights, just as randomizing the notes of a symphony would turn it into cacophonous sounds. Those who are interested in using computers to communicate culture and ideas need to develop command, not only of interactivity, but also sequentiality and form.

As theorists of hypertext over-emphasize interactivity, so too they exaggerate the divide between text in-print and on-line. Few can any longer participate actively in contemporary culture without using digital information technologies, and fewer still can do so with recourse exclusively to those tools. For several generations, printed text will co-exist with electronic text. The crucial question is not when the latter will displace the former, but how the two can work most effectively together.

Readers will work with text both in print and on-line for many years to come. Currently they do so with a strange gulf between the two forms of presentation. Electronic information technology has had little effect on the conventions of print presentation. A well-designed book often has the same appearance it did several centuries ago. Readers of printed materials still use the conventions developed long before electronic technology. The few recent innovations in conventions, for instance APA citations, predate digital technologies. As we will argue, this situation should change, but for now computers have had no influence on the presentation of text in print.

Since printed text has not changed, users of on-line text face an annoying situation. To work with text on-line, they must either import the old conventions of print awkwardly into the new medium or they must struggle with new conventions of hypertext that are too often unpredictable and ineffective. Hypertext conventions simply do not intersect well with print conventions. The information that can lead a reader to a passage in print may not help get her to the same passage on-line, even if it exists in that form. Likewise, encountering a text on-line often leaves the reader with scant clues about how to find it in print. We need to change this situation.

Print conventions harbor anomalies that were trivial as long as print was the sole medium of presentation. With print, presentation pertains partly to text and partly to the paper page. As the conventions of print developed, for the most part they soundly integrated text and page layout. Things pertaining to text received appropriate textual conventions -- chapter and section breaks, paragraphing, sentence punctuation, spacing to visually separate words, footnoting and the like. Things pertaining to the page received page conventions -- page margins, running heads, text justification, and so on. A few things got confused, with textual concerns met through page conventions, the most significant of which involves pagination.

Page numbers are attributes of book layout that have nothing integral to do with the text. Yet, since the early conventions of printing, readers and writers habitually use them to indicate locations in a text. As scholars increasingly work with text both in print and on-line, this anomaly becomes more and more problematic.

Quite apart from electronics, any serious user of printed texts has at one time or another encountered the basic problem. In the critical essay you are reading, the author cites something interesting; you have the book on your shelf; oops, your edition is not the one the author cited. The page references do not work and you are left thumbing in frustrated hope that you can chance upon the cited text. The problem is simple: page references do not really address locations in a text, even though we habitually use them for that purpose. That is the basic confusion and its consequences are substantial.

Pages, and page numbers, are attributes of books, not the texts presented in books. Page numbers in texts are a major inconvenience in an environment in which readers will work with text both in print and on-line. Citations and quotations rely for the most part on elements of the text -- author, title, chapter divisions, the words of the text itself. A crucial part of the citation -- the actual location of the material cited -- depends on the edition, not the text, for we use page numbers to address locations in the text. With a few great works of religion, literature, and thought, standard page references have become established -- Plato, Republic, 492b, will take one to a key passage for understanding its educational theory regardless of edition. But the great majority of citations are edition dependent because we use pagination, unique to each edition, to specify the location in a text.

A simple alternative will assign each paragraph in a text a sequential number. Unlike the page number, the paragraph number is an attribute of the text and it will be thoroughly device and edition independent. With such numbering, a citation need give only author, title, and paragraph number. The citation should work for all versions of the text, whether it is in print or on-line, a first edition or an excerpted reprint. The technique is simple: a sequential number becomes an attribute of each paragraph and pagination drops from use. "Paragraph," of course, can broaden its base significance beyond written text here, referring, in addition to a distinct unit of thought in writing, to an image or composition in graphics, a sequence in animation, a shot in video, and a phrase in music. Creators should number their "paragraphs," whatever the medium. Power and Pedagogy prototypes these techniques.

Device independent referencing will benefit readers, whether they use printed or electronic texts. Most serious readers now have access to a computer and a good printer. With these tools, the dichotomy between printed and electronic media should breakdown. We talk about "printed books," but really what we mean by printed books are "pre-printed books." Before they are read, before they are sold, before they are even published and distributed, books get printed in quantity, usually with the full press run bound as well. This consumes much paper and labor, requiring substantial capital, and it creates bulk, costly to inventory and to ship, and then to shelve in bookstores and libraries. A significant portion of the cost of books arises from the practice of pre-printing them.

With device independent referencing, publishers can distribute books electronically via networks and disks, and readers can print those books and parts of books that they want to have in hard copy, in a form that suits their needs -- large type for one, big margins for another, even a synthesized audio reading for a third. With device independent referencing, each can cite the text in a way that works easily and accurately for all. Best of all, for those willing to work with electronic text, device independent referencing will enable readers to execute hyperlinks across complex networks without needing to know much about the location or format of the work they seek.