Learning, Technology, and Education Reform in the Knowledge Age

or

"We're Wired, Webbed, and Windowed, Now What?"

Bernie Trilling and Paul Hood, WestEd

Originally published in
Educational Technology, May/June 1999

WestEd®
Improving education through research, development, and service

Learning, Technology, and Education Reform in the Knowledge Age
or
"We're Wired, Webbed, and Windowed, Now What?"

Bernie Trilling and Paul Hood, WestEd

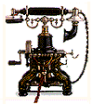
The year 2000 will mark the 10th anniversary of the arrival of the Knowledge Age in the United States. It will also mark nearly 20 years of efforts in the current round of education reform in the U.S. It's time to take a step back to a wide-angle view of the central roles learning and education will increasingly play in our new knowledge-based society. First, we will ask some basic questions about our newly arrived Knowledge Age, then we will survey the needed skills, theoretical supports and main features of this new learning landscape. We will then focus briefly on three current models of reform – "top-down," "bottom-up" and "systemic-mixed mode" – and their limited prospects for social traction and sustained change. Next we will examine a fourth reform alternative, one that arises directly out of the new demands of the Knowledge Age. This "turn around" strategy is already transforming learning and training in the worlds of business, medicine, science and technology, and is starting to do the same for public and private, K-16 education. Finally, we will zoom in close on the critical work to be done in bringing the powerful toolkits of educational technology to the service of an emerging alternative education model.

At the Turning Point of the Knowledge Age

Where was the party?

It happened quietly, without fanfare or fireworks. In 1991, U.S. spending for Industrial Age capital goods – things like engines, electrical distribution, metal-working and materials handling machinery, industrial equipment for mining, oil fields, agriculture, construction, etc., a total of $107 billion – was exceeded for the first time in U.S. history by the spending for information technology – computers and telecommunications hardware and software – which grew to a record $112 billion. This historic shift marks Year One of the Knowledge Age (Stewart, 1997, pp. 20-21). Since then, companies have spent ever more on equipment that makes, manipulates, manages and moves the bits and bytes of information than on machines that perform similar operations on the atoms and molecules of the physical world (Negroponte, 1995).

The shift from an industrial-based to a knowledge-based society changes the fundamental processes and values added to each step in producing a product or service, the so called "value chain" of work (see Figure 1).



Industrial Age:
Extraction => Manufacturing => Assembly =>
Marketing => Distribution => Products (& Services)

Knowledge Age:
Data => Information => Knowledge =>
Expertise => Marketing => Services (& Products)

Figure 1. Industrial Age vs. Knowledge Age Value Chain

Note that this does not mean that Industrial Age work in the world will (or can) ever go away. It does mean that with increasing automation and the export of manufacturing (and its environmental problems) to industrial-strength countries like China, industrial work in Knowledge Age countries like the U.S. will continue to fade to low levels, whereas the need for knowledge work in these countries will continue growing well into the 21st Century.

This turning point, decades in the making, forever tilts the balance of what is valued in our work and our society. This, in turn, changes what is needed to prepare for life and work in our society – the main concern of education.

At this transition, where the very purpose of education – cultivating knowledge and skills – becomes the centerpiece of our age, it is only appropriate to pause and take a fresh look at education and learning in our society and the new roles they will play as our Knowledge Age unfolds.

Six Basic Questions

Given the historic nature of this change, we must ask some basic questions:

1) Does this shift change the traditional aims of education in our society?
2) What skills will be necessary for success in the Knowledge Age?
3) What have we learned about learning that might help us gain these skills?
4) What does Knowledge Age learning really look like in practice?
5) How do we get there from here – which reform strategy will be effective?
6) How can we best apply learning technologies to support this alternative?

We will take up these questions, one by one, in the remainder of this article.

1) Does this shift change the traditional aims of education in our society?

There are four traditional reasons why education is considered so essential to society. Education empowers individuals to contribute to society, fulfill their personal talents, fulfill their civic responsibilities and to carry tradition forward.

Though these broad, societal goals have not, in principle, changed, our cultural context most certainly has. Having entered the Knowledge Age, our response to each of these goals shifts dramatically and brand new sets of demands appear, challenging our entire education enterprise (see Figure 2).

	Traditional Goals	*Knowledge Age Response*
	***Contribute to Society***	*Knowledge Work, Participation in the Global Economy*
	Fulfill Personal Talents	*Actualize Potentials with Knowledge Tools Support*
	***Fulfill Civic Responsibilities***	*Involved and Informed Democratic Decision-making*
	Carry Tradition Forward	*Build Identity from and Compassion for Multiple Cultures*

Figure 2. Aims of Education Reconsidered

Contribute to Society
To contribute well to our Knowledge Age society we need a new set of skills – knowledge work skills (more on this below). And now, when we apply these skills to our daily work, we participate in a vast, intricate web of global economic, informational, technological, political, social and ecological inter-relationships. We will all need to learn new ways to live and work in our highly complex, technological, information-rich world.

Fulfill Personal Talents
More and more of us are enjoying the benefits of powerful knowledge tools – computers and telecommunications hardware and software. They are enhancing our learning, our work, and our play. These "amplifiers," "storerooms," and "sensory extensions" for our thinking and communicating, are becoming "power

tools" for our personal development. But without strong societal initiatives to make these tools available to everyone, the existing disparities between "knowledge rich" and "knowledge poor" will only increase. And if the darker uses of these tools remain unchecked – addictive graphic violence and titillation, feelings of social isolation and even depression from over-immersion in electronic mediaspace, etc. – these negative effects may contribute to preventing many of our children from fully developing their talents (Postman, 1986; Papert, 1996; Healy, 1998).

Fulfill Civic Responsibilities

With freer access to a much wider spectrum of issues, facts, opinions and conversations that electronic media and the Internet bring to us, our potential for involved and informed participation in the democratic process has never been greater. At the same time, the need to become a "smart consumer" of information, to learn how to exercise discrimination and to filter the rushing media flood, has also never been greater (Tyner, 1998). And as fewer and fewer commercial media conglomerates control more and more of our sources of information, we must work ever harder to make careful choices from our abundant, daily media menu and to use critical judgement over our media diet.

Carry Tradition Forward

Increased worldwide mobility, immigration, inter-marriage, growing economic opportunity and other factors have led to a truly multicultural society in the U.S. With a diminishing majority soon joining a rainbow of ethnic and cultural minorities, the challenge now is for each of us to learn how to build and maintain our own identity from our given traditions, and from the pool of shared American traditions, and at the same time, to learn compassion and tolerance for the identities and traditions of others. Though this is not entirely new to our "melting pot" heritage, the scale and range of cultural and socioeconomic diversity is unprecedented. This will pose tough challenges to the preservation of social harmony in our society for a long time to come.

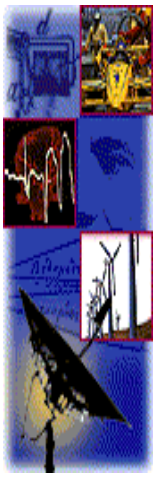
In short, though the traditional goals of education in our society remain the same in the Knowledge Age, the potential for reaching those goals, and for experiencing some stressful difficulties along the way, are both very high. The source of this stress has much to do with the inevitable lag between our powerful technical abilities and our very human inability to quickly shift habits of thought and social structures to meet new, large-scale challenges.

As we navigate this bumpy road into the Knowledge Age, we need to look closer at what the future will expect of us, what new sets of skills all learners will need to learn and all workers will need to apply to their work.

---

2) What skills will be necessary for success in the Knowledge Age?

Figure 3 outlines what we believe will be the key Knowledge Age survival skills, beyond the traditional, yet even more essential, three Rs. These seven skill sets represent a distillation of a wide variety of needs identified in a number of studies that examine future workplace skills (e.g., U.S. Dept. of Labor, 1992). Though there have been many ongoing efforts to cultivate these skills, they are still not yet recognized as priority education goals for all learners.



Seven Cs	*Component Skills*
Critical Thinking-and-Doing	*Problem-solving, Research, Analysis, Project Management, etc.*
Creativity	*New Knowledge Creation, "Best Fit" Design Solutions, Artful Storytelling, etc.*
Collaboration	*Cooperation, Compromise, Consensus, Community-building, etc.*
Cross-cultural Understanding	*Across Diverse Ethnic, Knowledge and Organizational Cultures*
Communication	*Crafting Messages and Using Media Effectively*
Computing	*Effective Use of Electronic Information and Knowledge Tools*
Career & Learning Self-reliance	*Managing Change, Lifelong Learning and Career Redefinition*

Figure 3. The Seven Cs: Knowledge Age Survival Skills

Critical Thinking-and-Doing
Knowledge workers need to be able to: define problems in complex, overlapping, ill-defined domains; use available tools and expertise, both human and electronic, for research and analysis; design promising solutions and courses of action; manage the implementations of these solutions; assess the results; and then continuously improve the solutions as conditions change.

Fluency with the design process, project management, quality management, and research methods will all be important, as well as understanding the specific content knowledge of the field involved, which will be changing dramatically and will have to be continuously refreshed "just-in-time." Online information databases, quick email access to experts, and Web-based courses are a few of the tools that will help support this "just-in-time" learning.

Creativity
Coming up with new solutions to old problems, discovering new principles and inventing new products, creating new ways to communicate new ideas, and finding creative ways to manage complex processes and diverse teams of people, will all be highly prized Knowledge Age skills.

Collaboration
Teamwork will often be the only choice for solving complex problems or for creating complex tools, services and products – multiple talents will be essential. From coordination and collaboration to compromise and consensus, the skills for effective, collaborative teamwork will be a necessary feature of work in the Knowledge Age.

Cross-cultural Understanding
As an extension of teamwork, knowledge workers will have to bridge differing ethnic, social, organizational, political, and content knowledge cultures in order to do their work. In an increasingly multicultural society, a growing global economy, a world of increasing technical specializations, and a flattened "network" organizational model, cross-cultural skills will become more and more valuable.

Communication
Knowledge workers will need to be able to craft effective communications in a variety of media for a variety of audiences. Given the bewildering number of communication choices available – printed report, electronic document, magazine article, e-zine article, book, e-book, print ad, TV ad, Web ad, phone call, cell phone call, Internet phone call, voice mail, telemarketing, fax, pager, Web page, e-mail, snail mail, spreadsheet, simulation, database, multimedia presentation, slides, overheads, floppy disk, tape, video, CD, DVD, radio, TV, Web-TV, teleconferencing, virtual reality – workers will be perpetually faced with choosing the right medium for the right message for the right audience, and with the challenge of doing it all as effectively and efficiently as possible.

Computing
Everyone in the Knowledge Age will have to be able to go beyond basic computer literacy to a high level of digital fluency (Papert, 1996, pp. 26-30; Gilster, 1998) and comfort in using a variety of computer-based tools to accomplish the tasks of everyday life. Needless to say, those who master the knowledge tools of the Knowledge Age will be much more successful at school and at work than those who do not.

Career and Learning Self-reliance
In an age of "at will" employment and increasing temporary and contract work, knowledge workers will have to manage their own career paths and their own

continuous learning of new skills (Bridges, 1994). Since most work will be high-skilled, project-based work (as opposed to low-skill service work or factory line-work), the ability to manage a progressive series of shifts from one project to the next and to quickly learn what is needed to be successful in each project, will all be essential to career survival and lifelong learning in the Knowledge Age.

As we look over this list of skills, an unsettling set of questions arises: How will we ever get to these new skills when we're still struggling with doing a good job on the three Rs? Where are these additional skills being learned in our existing education system? Where are the standards that set the learning of these skills as goals? Where are the tests and assessments that are measuring the learning of these skills? Where are the curricula and learning programs that are building these skills from the earliest ages right through to adult education?

We must remind ourselves that, in many ways, we are still early explorers having just arrived in this brave new Knowledge Age world. We have not confronted a set of large-scale changes as challenging as these since the Industrial Age steamed and cranked itself out of a centuries-old Agricultural Age back in the middle of the 19th century.

One can also argue, though, that we have seen these changes coming for quite a while (well before the *Nation at Risk* report in 1983) and that compared to the pace of change in the competitive business environment, education might be the last place to look for speedy action. We must also remember that education in the U.S. is firmly lodged in a political process where it is far easier to secure support for quick fixes that attack symptoms than it is to find the political will to confront the root ailment of an elaborate education structure designed for an age that just passed.

Despite the challenges, there *are* a growing number of school programs and even whole schools where these new skills are being learned and where learners are being prepared for the knowledge work ahead (Schauble & Glaser, 1996; ASCD, 1997; Education Week/The Milken Exchange on Educational Technology, 1998).

And fortunately, what we've recently learned about learning provides substantial support for the acquisition of these Knowledge Age skills.

---

3) What have we learned about learning that might help us gain these skills?

While there is still much discussion and debate over aspects of modern learning theory and how best to turn it into practice (Duffy & Jonassen, 1992; Perkins, 1992a; Resnick, 1996; Willis 1998), a broad consensus has formed around a few

key principles. We offer a very short summary list that highlights the major findings of over two decades of progress that educators, developmental and cognitive psychologists, neuropsychologists, learning and instructional theorists, sociologists, academic researchers, and others have achieved in adding to what we know about how we learn (see Figure 4).

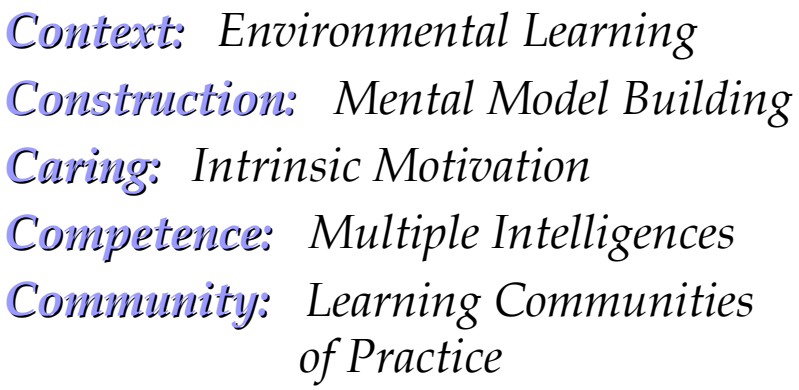


Figure 4. The Five Cs of Modern Learning Theory

Context

We have learned that context plays a very significant part in learning, that the environmental conditions for learning (objects, people, symbols, and their relationships) are much more influential than we've previously thought, and that the transfer of knowledge from one context to another is not often successful. The demand for more "authentic" learning tasks that match real world conditions comes directly from these findings, as well as the desire to have rich learning environments that offer a wide variety of contextualized opportunities for discovery, inquiry, design, practice, instruction and constructive exploration. This approach coincides with the need to become proficient in solving real world problems and to exercise critical thinking-and-doing in the Knowledge Age.

Construction

A great deal has been learned about how we build mental models, assimilate new experiences, accommodate changes to our models as we confront experiences that don't quite "fit," and even hold important misconceptions about the world as necessary bridges to more "accurate" models. These findings underscore the educational importance of constructing models, both physically (with wood blocks, *LEGOs*, etc.) and "virtually" (drawings on paper and computer screens, simulation modeling with *SimCity,* etc.). These "visceral and virtual" modeling activities provide strong external supports for the internal model-making going on inside our heads. We now can see just how important design, simulate and build activities are in learning, for they match the constructive, modeling and designing aspects of how we learn, and they also

prepare us for the methods we will use to accomplish our future knowledge work (Papert, 1993).

Caring

We can rely on a rich literature of affective studies and reports from practice that clearly demonstrate the advantages of intrinsic over extrinsic motivation in learning and the development of deeper understandings (Covington, 1998). Recent project-based and problem-based learning programs where learners define their own projects (with careful guidance) and set the criteria for which they will be evaluated (student-generated rubrics that reflect current standards) have shown just how much learning can happen when students genuinely care about their work (e.g., The Project-based Learning Network, at www.autodesk.com/foundation/pbl). This fully supports the Knowledge Age need to develop self-reliant and self-motivated learners and workers who have the persistence to creatively solve difficult problems and find answers to tough, complex questions.

Competence

Though there remains some lively debate over what exactly are the inherent "modules of intelligence," there is now no question that competence comes in a variety of flavors and intelligence is exhibited in a wide assortment of behaviors. Whether it's a triarchic mind (Sternberg, 1988), seven (or now "8½") intelligences (Gardner, 1983; 1993; 1998) or a society of interacting mini-modules in the mind (Minsky, 1986) we know enough now to encourage multiple learning approaches to match diverse learning styles and multiple ways of expressing understanding. This corresponds with the Knowledge Age need to benefit from multiple talents in the creative solving of problems in diverse teams, and in the sensitive design of services and products for diverse audiences.

Community

A strong case has been made for the social aspects of learning and the importance of learning from communities of practice (Vygotsky, 1978; Lave & Wenger, 1991; Wenger 1998). This extends the value of learning in context, discussed above, to the social and cultural realms of group interaction, peer and mentor relations, group culture, and the environmental influences of tools, settings, and techniques. Again, this firmly supports the Knowledge Age need to use collaborative, community-based approaches to problem solving and to learn from a variety of communities of practice in the pursuit of lifelong learning.

In summary, recent advances in theory indicate that the skill demands of the Knowledge Age are very consistent with the ways we naturally learn, solve problems, find answers to questions, and develop our abilities to think and act.

Fortunately, there is a close match between theory and Knowledge Age needs; unfortunately, current educational practice does not often match modern theory.

---

4) What does Knowledge Age learning really look like in practice?

From our analysis of educational programs that appear successful in developing the Knowledge Age skills outlined above, and from programs that are also successfully integrating information and knowledge tools into the fabric of everyday learning, we have derived a list of common characteristics of Knowledge Age learning practice. We have contrasted these methods with those of programs that better fit the Industrial Age learning model, still the predominant mode of practice in our current educational system (see Figure 5).

Industrial Age	*Knowledge Age*
Teacher-as-Director	*Teacher-as-Facilitator, Guide, Consultant*
Teacher-as-Knowledge Source	*Teacher-as-Co-learner*
Curriculum-directed Learning	*Student-directed Learning*
Time-slotted, Rigidly Scheduled Learning	*Open, Flexible, On-demand Learning*
Primarily Fact-based	*Primarily Project- & Problem-based*
Theoretical, Abstract Principles & Surveys	*Real-world, Concrete Actions & Reflections*
Drill & Practice	*Inquiry & Design*
Rules & Procedures	*Discovery & Invention*
Competitive	*Collaborative*
Classroom-focused	*Community-focused*
Prescribed Results	*Open-ended Results*
Conform to Norm	*Creative Diversity*
Computers-as-Subject of Study	*Computers-as-Tool for all Learning*
Static Media Presentations	*Dynamic Multimedia Interactions*
Classroom-bounded Communication	*Worldwide-unbounded Communication*
Test-assessed by Norms	*Performance-assessed by Experts, Mentors, Peers & Self*

Figure 5. Industrial Age vs. Knowledge Age Learning Practice

From studying this chart we can begin to draw a few conclusions. First, we are clearly looking at a paradigm shift in educational practice. So many of the behaviors beneficial for Industrial Age learning become their near opposites in the Knowledge Age. Where learning through facts, drill and practice, and rules and procedures was so adaptive in the Industrial Age, now learning through projects and problems, inquiry and design, discovery and invention is more fitting for the times.

Second, we can see how difficult it really is to achieve systemic reform when the "pull" of the older paradigm tends to reabsorb forays into the new order. Lacking a full-blown shift to Knowledge Age practice, the small advances we make in changing our methods eventually slip back into old and familiar Industrial Age habits.

Third, though we have emphasized the polarities, it is probably more accurate to view each pair of Industrial and Knowledge Age characteristics more as a continuum. And though we are likely to see many examples of fairly "pure" Industrial Age practice, and far fewer examples of "pure" Knowledge Age learning environments, we are even more likely to find a wealth of hybrid blends drawn from both columns. Even when the leap to mostly Knowledge Age methods has been made, the need for individual Industrial Age practices (like memorizing facts) will always remain. In the eclectic evolution of educational practice, previous methods don't entirely disappear, they are just used less frequently than the new ones.

A fourth observation is that Knowledge Age learning practices do correspond well with modern theory about how we learn. From project- and problem-based learning to collaborative and community-focused activities, from an emphasis on real world learning in context to the increased focus on learner-motivated actions, Knowledge Age practices are well supported by modern learning theory (or is theory "adapting" to the needs of the times?).

Fifth, at first glance, it looks as though Knowledge Age practice is quite dependent on modern knowledge tools – computers and telecommunications – to be really successful. But on closer inspection, most of the Knowledge Age characteristics (except the three specifically addressing the use of computers, multimedia and communications) can be accomplished without the benefit of any of our modern tools. In fact, most of these practices were in place in Dewey's turn-of-the-century Chicago Laboratory School and later in the Dewey-inspired progressive education schools of the 1920's and 30's in New York City, long before PC's and the Internet (Tanner, 1997).

Though information and communications technologies are important catalysts for moving us into Knowledge Age learning methods, we must always remember that it's the practice and the results, not the tools, that make a difference. We can (and do) add lots of high-tech hardware and software to our classrooms without changing our practice, and end up with "electronic horse saddles," no more effective (and most often less) than before in transporting our children into our high-speed Knowledge Age.

And last, but most importantly, this new paradigm for learning presents a tremendous challenge and opportunity to the professional development, both preservice and inservice, of our teachers. In many ways, it represents a redefinition of the teaching profession and the roles teachers play in the learning process (Fisher, Dwyer & Yocum, 1996; Sandholtz, Ringstaff & Dwyer, 1997). Though the need for nurturing, caring, compassion and cultivating the best in our children will always remain at the core of teaching, the new demands of the Knowledge Age bring a whole new set of learning principles and behaviors into practice.

---

5) How do we get there from here – which reform strategy will be effective?

From Teaching Titanic to Learning Lifeboats?

As we have seen, we are facing an unprecedented shift to a new kind of learning environment. It seems that moving deck chairs and polishing the brass on the Industrial Age teaching "Titanic" will most likely not get us to our desired destination. But inventing new high-tech learning "lifeboats" looks like a difficult task too, especially when the learning gear may need to be upgraded every six months or so.

What is the proper reform vehicle that will carry education and learning on course to our Knowledge Age destination?

Moving Deck Chairs on the Titanic?

There have been three predominant approaches to improving our existing educational system: "top-down," "bottom-up" and "systemic-mixed mode" (Murphy, 1990). Each has brought some degree of success to the reform of certain aspects of education, with most of the recent efforts focused on applying the more difficult "systemic-mixed mode" approach.

Top-down

Whether initiated at the national, state or local level, the top-down approach has focused mainly on standards, assessment tests, accountability, and incentives to

guide educational change efforts. Mandated structural changes, such as class-size reduction, have also been a part of this approach.

A great deal of effort has been expended to create rigorous new standards and frameworks for all subject areas (to the point where we now have multiple, loosely coordinated sets of standards for some subjects); to expand the use of tests and assessments of both learners and teachers (including national teacher certification testing); and to broaden the range of experimentation in creating incentive structures and structural changes to schooling (including higher ceilings on the number of charter schools). Despite these efforts, there remains a wide consensus that at the level of everyday practice in classrooms across our country, we are still not seeing the kinds of improvements, in test scores and other measures, that would indicate that these top-down reforms are working.

The strongest criticism of this approach focuses on the core of its reform strategy – what we're testing and measuring. When we examine the knowledge and process skill needs of the age we have just entered (the "seven Cs" beyond the three Rs), and then look at the predominantly fact-based testing of shorter-term memory that is still the main focus of our tests, we have a strong clue as to why many of these top-down reforms are not succeeding. A basic tenet of quality management states that "you can only change what you measure." Unless we begin to measure the kinds of skills needed in the Knowledge Age, we will never know whether our reform efforts are really helping or harming the development of these essential skills.

Bottom-up

It is in using the bottom-up approach that we have seen a thousand flowers bloom. From creative teacher-led and even student-inspired innovations to whole school experiments in the re-invention of learning (e.g., Comer's School Development Program, Levin's Accelerated Schools Project, Sizer's Coalition of Essential Schools, etc.), and from research-based program innovations (e.g., Success for All) to experiments in for-profit school management (e.g., the Edison Project, Advantage Schools, National Heritage Academies), we are witnessing a renaissance of bottom-up educational innovation.

The big question remains though, can we really "scale up" and sustain these innovations, which so often depend on the leadership of individual champions, on temporary excitement over participation in new change experiments (the Hawthorne effect), and more significantly, on temporary jolts of additional funding and support (grants and community donations) for programs that are most often not sustainable after the money runs out?

Systemic-mixed mode
Because of the limitations of both the top-down and bottom-up approaches, recent efforts have focused on combining the two, the so-called "systemic" reform strategy (O'day & Smith, 1993). Top-down initiated leadership and support for the development and coordination of bottom-up initiatives, bottom-up initiatives that gain support and coordination from the top down, and many variations on these themes are all being tested in our recent wave of systemic reforms.

Some of these mixed-mode initiatives (e.g., the Annenberg Challenge) are having important larger-scale successes, but the pace of change appears very slow and the challenges of sustaining hard-won reforms remain extremely daunting.

Leaping to the Learning Lifeboats?
With almost 74 million students currently in K-16 U.S. classrooms, we must continue to improve our existing educational system. But shouldn't we also consider supporting the rise of an alternative system (Schlechty, 1997; Hill, Pierce & Guthrie, 1997), one that is more in tune with Knowledge Age needs and knowledge tools, and that is increasingly proving successful in business, science, medical and technology research, and other knowledge-based institutions?

As we have shown, in education there is an emerging profile of Knowledge Age learning in actual practice, thanks to the trailblazing work of pioneering teachers, trainers, educators and students. We know that the skill demands of the Knowledge Age look quite different from those of the age we have just passed. The kinds of knowledge tools we now have at our disposal are much more powerful than those available even three or four years ago. What we now know about learning also supports the very styles of learning that will be necessary for success in the Knowledge Age.

These three Knowledge Age forces – the new demands for knowledge work skills, the new possibilities that our knowledge tools offer, and the support for new ways of learning from learning theory – are all converging on a new, alternative model of learning and education (see Figure 6).

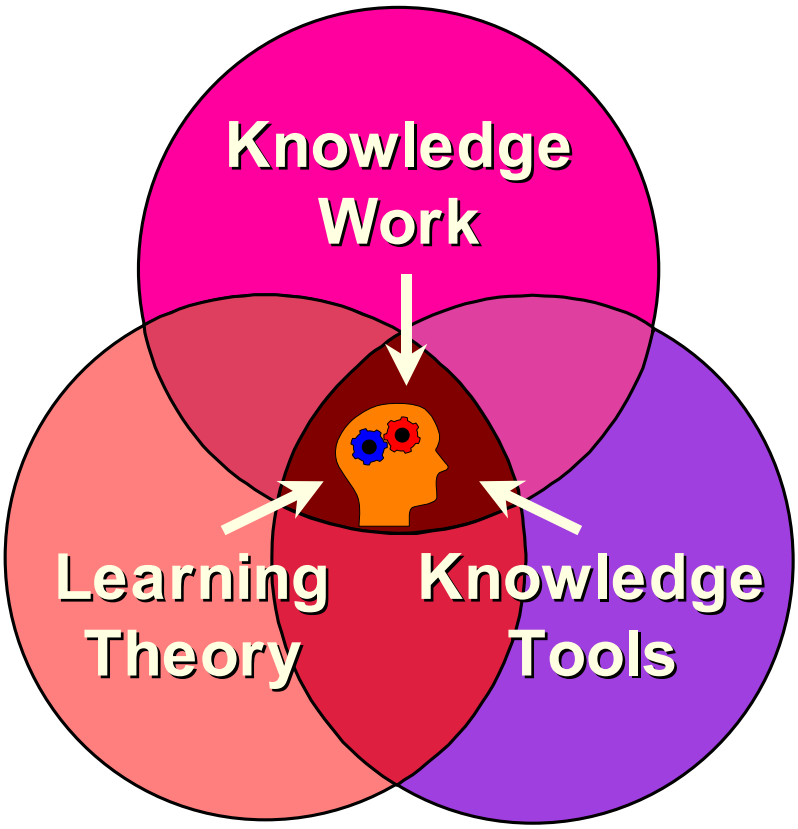


Figure 6. The Knowledge Age Learning Convergence

What will this new Knowledge Age education model really look like?

An Alternative Model: Knowledge Age Community Learning Centers
From reviewing our earlier list of successful Knowledge Age practices (Figure 5), and the chart of Knowledge Age skills (Figure 3), and from observations of programs that demonstrate these qualities (including business and industry examples which are much farther along than public education), we can begin to see some patterns and trends. Some of these new learning environments are starting to become "extended learning centers" that look and feel more like rich cultural or community centers than schools (Dreyfoos, 1998).

With a little imagination and some creative speculation, we can begin to outline what some of these learning centers might become:

> A hybrid campus open 7 days a week, that houses a public school (or schools) as well as a variety of non-profit and for-profit (and partnerships of non- and for-profit) educational, social, health, community, and

recreational organizations and small businesses, including a learning supplies store, copy center, family-oriented restaurant, etc.; all locally orchestrated by a site "principal" and regionally managed by a "district" executive management team in charge of negotiating contracts and maintaining educational balance and quality at all of the district campuses.

Small groups of similar-age learners starting and ending each day in their "homeroom" where their primary learning advisor (still called "teacher") presents the day's activity and class choices, leads reflective discussions on issues and topics of current interest, reviews progress toward mutually contracted goals, coaches and guides students through their learning hurdles, coordinates the resources and help needed, and provides caring support for the social and emotional needs of each of their homeroom learners.

A rich schedule of "live" instructional classes, presentations, demonstrations, field trips, and discussions led by local and distant (through teleconferencing) teachers, experts and other students in formal (classroom) and informal (meeting room) spaces.

Small mixed age teams of learners working on a wide variety of projects under the guidance of "project advisors" (teachers, parents and community members) with exhibits of past projects displayed throughout the campus - a dynamic "museum" of project-based learning.

A wide assortment of "visceral" learning resources – well-stocked library-museum-lab-workshop-technology-art-construction spaces, multipurpose music-dance-theater-recreation spaces, and outdoor garden-farm-biology-ecology spaces.

Plenty of access to "virtual" resources – portable computing with local network connections to learning and reference tools, productivity applications and personal databases, and global access to Web-based information resources and conferencing tools.

A wide variety of "just-in-time" learning choices for students and teachers from Web-based reference databases, libraries and resource centers, online courses and online experts and mentors.

Online, standards-based assessments and certifications of knowledge and skills mastery, including simulation exercises and electronic portfolio reviews by learning advisory teams that include students, teachers and community experts, as well as in-person reviews of hands-on performance in authentic tasks by both teachers and students.

These Knowledge Age learning centers will extend into the community, with apprenticeships, local service projects, storefront mini-businesses, neighborhood projects, etc., as well as into the home through telecommunications. And the community will extend back into the learning centers with active community participation in a wide variety of projects and programs.

Community college campuses, in many ways, are the early prototypes of this model, though they still retain many Industrial Age practices within their traditional classrooms.

Getting Ready for the Leap – the "Turn-around" Reform Strategy

Having taken a brief (albeit speculative) glimpse of where we think we are headed, we can now take a look at how we might get there – a reform strategy that will lead to this alternative education model.

The "turn around" reform strategy is based on promoting three important enabling trends – increased competition in education and training, decreased educational costs from the use of educational technology, and the effective use of performance-based educational practices and measures.

Competition to traditional public schools is growing very rapidly. Charter schools, private schools, for-profit schools, outsourcing of learning services to both non-profit and for-profit educational service providers, and after school tutorial programs are all on the rise. There is a strong desire on the part of entrepreneurs and the venture capital community to "break into" the $500 billion K-16 education market that is mostly "locked up" in governmental and non-profit programs (Gay, Dobell & Dunlevy, 1998).

Though the risks of increased competition are high and must be carefully contained – threats to equal access and equal opportunity, the possible loss of democratic community control, the blurring of marketing and learning under commercialization, etc. – the benefits of a well managed, balanced level of competition may in the long run far outweigh the risks. Some of these benefits include lowered costs and higher efficiencies; access to a much wider pool of dollars and management expertise from the for-profit community; the use of the entire community as a classroom and learning laboratory; after school, weekend, and summer learning programs; on campus health, social, and recreational programs and services; and wider learning choices for students.

As information and communications technology costs continue to plummet while technology performance soars (Moore's Law), and as we increasingly integrate these tools into our educational infrastructures and learning practices, administration costs should drop and efficiencies rise, more resources should be

freed for classroom learning (currently a little over 50% of educational expenditures actually reach the classroom), and more effective learning practices with integrated technology use should occur. This assumes, of course, that the increased competition outlined above will force schools and other educational service providers to continually transform their programs and practices to benefit from the gains in performance and the lower costs of technology.

Just as performance-based approaches are revolutionizing business and industry – total quality management, portfolio-based assessments of employees, and electronic performance support systems with online knowledge databases and quick access to experts and mentors – applying these practices to education will help focus change and reform toward the new model. Much work will need to be done to adapt and develop these tools and techniques for education and learning, especially in the tracking of student performance toward meaningful standards and goals, and in the devising and monitoring of common performance and quality measures for all types of educational service providers.

The "Top-down, Bottom-up, Turn-around" Reform Dance

U.S. public and private agencies, institutions and programs dedicated to improving education and training are facing a very perplexing situation. They must perform a very difficult and intricate reform "dance." They must combine top-down and bottom-up steps to more systemically improve the existing education system, while simultaneously executing "turn-around" moves to prepare for leaps to an alternative education model still in its early stages (not an easy ballet!). And it is in this emerging alternative learning model that educational technologies will play an increasingly important supporting role.

---

6) How can we best apply learning technologies to support this alternative?

The gap between what our educational technologies can do and what they are actually doing in everyday classrooms and homes is still very wide. And some of the trends are truly disturbing:

> Educational software companies are merging into a few giant "edutainment" mega-corporations which often abandon the more difficult high-investment, lower-profit "edu-" development efforts in favor of lower-investment, higher-profit "-tainment" titles. (A recent case in point: The Learning Company, itself a product of multiple mergers, was purchased by Mattel, the toy maker, best-known for the Barbie doll.)
>
> Large school-based education software developers like Computer Curriculum Corporation and Jostens Learning are struggling to develop

new curriculum models as revenues from their large-scale, traditional drill-and-practice-style learning systems level off and start to fall.

The Web is starting to look more like the world's largest shopping mall than a global library, basing much of its revenue model on the same advertising strategy that has made so much of commercial radio and television of so little value to learning.

Billions of dollars are being spent on connecting schools, libraries and homes to the ever-expanding information infrastructure, while comparatively little is being invested in the learning content and support that will actually appear on our computer screens once they're connected.

On the positive side, there are promising tools for learning being developed by educational researchers and developers (Means, 1994; Center for Innovative Learning Technologies, www.cilt.org), innovative uses of technology are appearing in many more learning settings each day (ASCD, 1997; Education Week/The Milken Exchange on Educational Technology, 1998; and www.milkenexchange.org), and the tools, environments and methods for creating learning products are continuing to improve (Druin & Solomon, 1996).

"We're Wired, Webbed, and Windowed, Now What?"
What are the technology and content components of effective learning environments that will help answer this question (Perkins, 1992b)? We propose three integrated modules as the minimum for building effective Knowledge Age learning environments (see Figure 7).

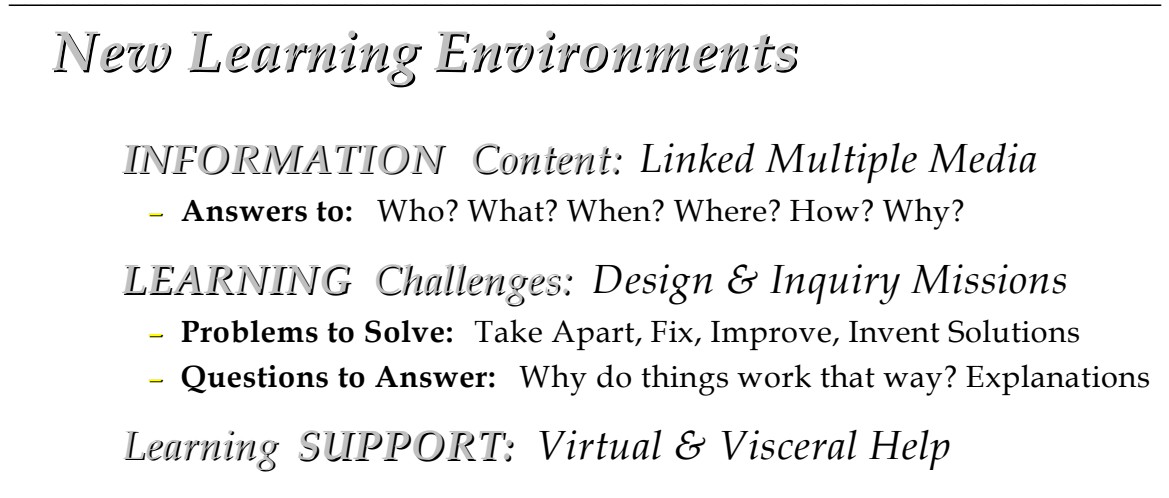


Figure 7. New Learning Environments

Information Content
Though there are many examples of multimedia CD-ROM encyclopedias covering vast areas of knowledge (like *Encarta* or the *World Book Encyclopedia*), there are still very few multimedia reference works targeted at specific subject matter areas that are available to everyone on the Web and that offer a structured gateway to other related Web resources.

These subject-focused multimedia references must provide a simple interface that help learners find answers to the basic questions asked about any subject – Who? What? When? Where? How? and Why?

Even more importantly, these reference resources must not be just static facts. Where possible, they need to use animations and interactive simulations to explain the processes and dynamics of the subject, with online links to community and expert resources for help in finding the answers to the more difficult questions.

Learning Challenges
The style of the learning activities in this environment must be consistent with Knowledge Age needs. Learning materials must provide more authentic design challenges where learners can collaborate on creating solutions to problems they care about.

Problem solving leads to questions and the search for answers – learners then have a reason to use the informational resources available and a motivated context for learning. Multimedia stories and adventures can help keep the engagement level high, but these must be integral to the learning design and appropriate for the intended audience, not a thin marketing add-on. On-screen simulation activities and hands-on kits and construction materials must also be an integral part of the design so that there is a healthy balance between virtual interaction and visceral, real world activities.

Though this "inquiry through design" process (Baumgartner & Reiser, 1997) can provide a highly motivating context for learning, there needs to be strong support for getting past the necessary frustrations and creative blocks that are natural parts of the design and inquiry processes.

Learning Support
Knowledge Age learners need support in developing their design and construction skills, their inquiry and answer-finding strategies, their creative and critical thinking skills, their project management skills, and their personal

management abilities, such as setting goals, assessing their own performance, staying motivated and managing their own learning process.

Good trainers, teachers, mentors, counselors and parents have been the traditional sources of this kind of support and will continue to be throughout the Knowledge Age. But more and more of this help can be delivered through Web-based tools and databases, as well as through electronic contact with members of the relevant communities of practice.

We will need Knowledge Age tools for creating and sharing electronic portfolios of work on the Web, for enabling multimedia discussions and collaborations, for getting quick help when needed, and for supporting all the stages of problem solving, inquiry and design.

Top 10 Challenges for Educational Technology

In summary, we offer the following ten-point "challenge list" for educational technologists, curriculum developers, software designers and developers, learning materials publishers, engineers, technologists, scientists, educators, trainers, teachers, parents, students, and entrepreneurs who want to make a valuable contribution to Knowledge Age learners and workers:

1. We need more effective models of learning programs that balance the "virtual and the visceral" – effectively combining on-screen activities with hands-on construction kits, design challenges, probeware, discovery labs, and real world explorations.

2. We need better Web-based multimedia reference sites for learning with simple interfaces and search engines, interactive simulations, comprehensive and updated guides to related Web sites, and simple tools for learners and experts to contribute their ideas and comments to the knowledge base.

3. We need a wealth of high-quality, instructional and constructional learning simulations and tools for the creation of simulations of all kinds, from games and scenario-based simulations to virtual construction kits and virtual simulators of complex environments and processes (Hood, 1997; Schank, 1997).

4. We need a quantum leap in ease of use and useful results in information searching, organizing and reporting tools, especially for the Web, and for databases of content knowledge and learning activities.

5. We need to make the entire database development, sharing, and maintenance process much simpler so that we can more easily create useful online

knowledge bases; dynamic, database-driven Web sites; personal learning history databases with multimedia portfolios of work; and large-scale education information systems that help us track Knowledge Age educational performance.

6. We need much better online collaboration and communication tools so that online discussions, live presentations with audience questions, groupwork, surveying and polling, and getting help online can actually be fun.

7. We need online learning assessment systems based on both the 3 Rs and the 7 Cs that combine simulations, concept mapping, reflective essay questions, portfolio presentations and the reporting of results from performance-based tasks. We also need a system to make it easy for content and learning experts to help review and comment on these portfolios and performance tasks.

8. We need more places for designing and constructing "gizmos, gadgets, and useful things" – workshops, labs, "garages," etc. – with real tools, construction materials, bins of parts, safe places to put things together and take things apart, and with access to online construction tips and exhibits of other students' inventions and experiments. This sort of constructive "tinkering," so valuable to learning, is fast becoming an endangered species in our ecology of educational experiences.

9. We need to apply all of our educational technology talent to the challenge of preparing teachers, parents and other helpers and learning guides to effectively integrate the use of all kinds of technologies, from hand lenses to supercomputers, into the everyday experiences of all learners.

10. We need to go outside, breathe deep, take a walk, smell the flowers, and forget about technology at least once a day.

We have seen some of the important work that must be done for technology to continue being an effective catalyst for learning and education reform. These are just a few of the needed pieces in a complex, 3-D educational jigsaw puzzle of social, political, economic, infrastructural and, most important, human components.

The challenges that our Knowledge Age brings to learning and education are great, but the promise of a new Renaissance of learning and knowledge in our society is even greater. There is much good work to be done in helping to make this promise a reality for all lifelong learners and workers in our new Knowledge Age.

References

Association of Supervision and Curriculum Development (ASCD) (1997, November). Integrating Technology into Teaching (entire issue). *Educational Leadership* 55(3).

Baumgartner, E. & Reiser, B. J. (1997). Inquiry Through Design: Situating and Supporting Inquiry Through Design Projects in High School Science Classrooms. A Paper presented at the 1997 Annual Meeting of the National Association for Research in Science Teaching (NARST).

Bridges, W. (1994). *Job Shift: How to Prosper in a Workplace Without Jobs.* Reading, MA: Addison-Wesley Publishing Company.

Center for Innovative Learning Technologies, http://www.cilt.org

Covington, M. (1998). *The Will to Learn: a Guide for Motivating Young People.* Cambridge, U.K.: Cambridge University Press.

Dreyfoos, J. G. (1998). *Full-Service Schools: a Revolution in Health and Social Services for Children, Youth and Families.* San Francisco, CA: Jossey-Bass Publishers.

Druin, A. & Solomon, C. (1996). *Designing Multimedia Environments for Children.* New York: John Wiley & Sons.

Duffy, T. M. & Jonassen, D. H. (Eds.) (1992). *Constructivism and the Technology of Instruction: a Conversation.* Mahwah, NJ: Lawrence Erlbaum Associates.

Education Week/The Milken Exchange on Educational Technology (1998, October). Technology Counts '98: Putting School Technology to the Test (special supplement). *Education Week* 18(5).

Fisher, C., Dwyer, D. C., & Yocam, K. (1996). *Education & Technology: Reflections of Computing in Classrooms.* San Francisco, CA: Jossey-Bass.

Gardner, H. (1983). *Frames of Mind: the Theory of Multiple Intelligences.* New York: Basic Books, Inc., Publishers.

Gardner, H. (1993). *Multiple Intelligences: the Theory in Practice.* New York: HarperCollins Publishers, Inc.

Gardner, H. (1998). Are There Additional Intelligences? The Case for Naturalist, Spriritualist, and Existential Intelligences. In Kane, J. (1999). *Education, Information and Transformation* (pp. 111-131). Upper Saddle River, NJ: Prentice-Hall, Inc.

Gay, R., Dobell, B., & Dunlevy, A. (1998, November). *The Age of Knowledge: the Growing Investment Opportunity in Education, Corporate Training and Child Care.* San Francisco, CA: NationsBanc Montgomery Securities.

Gilster, P. (1998). *Digital Literacy.* New York: John Wiley & Sons, Inc.

Healy, J. M. (1998). *Failure to Connect: How Computers Affect Our Children's Minds – for Better and Worse.* New York: Simon & Schuster.

Hill, P. T., Pierce, L. C. & Guthrie, J. W. (1997). *Reinventing Public Education: How Contracting Can Transform America's Schools.* Chicago, IL: The University of Chicago Press.

Hood, P. (1997). *Simulation as a Tool in Education Research and Development: A Technical Paper.* Washington, DC: Council for Educational Development and Research.

Lave, J. & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation.* Cambridge, U.K.: Cambridge University Press.

Means, B. (1994). *Technology and Education Reform.* San Francisco, CA: Jossey-Bass.

The Milken Exchange on Education Technology, http://www.milkenexchange.org

Minsky, M. (1986). *The Society of Mind.* New York: Simon & Schuster, Inc.

Murphy, J. (1990). *The Educational Reform Movement of the 1980's: Perspectives and Cases*. Berkeley, CA: McCutchan Publishing Company.

Negroponte, N. (1995). *Being Digital.* New York: Alfred A. Knopf, Inc.

O'day, J. & Smith, M. (1993). Systemic Reform and Educational Opportunity. In Fuhrman, S. (ed.) (1993). *Designing Coherent Education Policy.* San Francisco, CA: Jossey-Bass.

Papert, S. (1993). *The Children's Machine: Rethinking School in the Age of the Computer.* New York: HarperCollins Publishers, Inc.

Papert, S. (1996). *The Connected Family: Bridging the Digital Generation Gap.* Atlanta, GA: Longstreet Press, Inc.

Perkins, D. (1992a). *Smart Schools: Better Thinking and Learning for Every Child.* New York: The Free Press.

Perkins, D. (1992b). Technology Meets Constructivism: Do They Make a Marriage? In Duffy, T. & Jonassen, D. (Eds.), *Constructivism and the Technology of Instruction: A Conversation.* (pp. 45-56). Mahwah, NJ: Lawrence Erlbaum Associates.

Postman, N. (1985). *Amusing Ourselves to Death: Public Discourse in the Age of Show Business.* New York: Viking Penguin, Inc.

Project-Based Learning Network, http://www.autodesk.com/foundation/pbl

Resnick, M. (1996). Toward a Practice of "Constructional Design." In Schauble, L. & Glaser, R., (Eds.) *Innovations in Learning: New Environments for Education.* (pp. 161-174) Mahwah, NJ: Lawrence Erlbaum Associates.

Sandholtz, J. H., Ringstaff, C. & Dwyer, D. C. (1997). *Teaching with Technology: Creating Student-Centered Classrooms.* New York: Teacher's College Press.

Schank, R. (1997). *Virtual Learning.* New York: McGraw-Hill.

Schauble, L., & Glaser, R., (Eds.) (1996). *Innovations in Learning: New Environments for Education.* Mahwah, NJ: Lawrence Erlbaum Associates.

Schlechty, P. C. (1997). *Inventing Better Schools: an Action Plan for Educational Reform.* San Francisco, CA: Jossey-Bass.

Sternberg, R. (1988). *The Triarchic Mind: a New Theory of Human Intelligence.* New York: Penguin Books.

Stewart, T. A. (1997). *Intellectual Capital: the New Wealth of Organizations.* New York: Doubleday.

Tanner, L. N. (1997). *Dewey's Laboratory School: Lessons for Today.* New York: Teacher's College Press.

Tyner, K. (1998). *Literacy in a Digital World: Teaching and Learning in the Age of Information.* Mahwah, NJ: Lawrence Erlbaum Associates.

U.S. Department of Labor, Secretary's Commission on Achieving Necessary Skills (SCANS). (1992). *Learning a Living: a Blueprint for High Performance.* Washington, DC: U.S. Department of Labor.

Vygotsky, L. L. (1978). *Mind and Society: the Development of Higher Psychological Processes.* Cambridge, MA: Harvard University Press.

Wenger, E. (1998*). Communities of Practice: Learning, Meaning, and Identity.* Cambridge, U.K.: Cambridge University Press.

Willis, J. (1998, May/June) Alternative Instructional Design Paradigms: What's Worth Discussing and What Isn't. *Educational Technology,* 38(1), 5-16.