Emerging Technologies and Distributed Learning in Higher Education

Chris Dede, George Mason University

This chapter depicts visions of how sophisticated information technologies may influence the nature of higher education over the next couple decades. Its purpose is not to present predictions of an inevitable future, but instead to stimulate reflection about how we can collectively evolve colleges and universities by creatively moving beyond almost unconscious assumptions we hold about teaching, learning, and schooling. The rapid advance of information technology is driving shifts in every other form of societal institution, in ways that are often unplanned and sometimes unfortunate. Hopefully, the academy can do better in determining its own fate through deliberate choice and collaborative action to achieve the full educational potential of advanced computers and telecommunications.

Emerging Interactive Media

The development of the Internet is fostering the creation and proliferation of emerging interactive media, such as the WorldWide Web and shared virtual environments. A medium is in part a channel for conveying content; as the Internet increasingly pervades society, university instructors can readily reach extensive, remote resources and audiences on-demand, just-in-time. Just as important, however, a medium is a representational container enabling new types of messages (e.g., sometimes a picture is worth a thousand words). Since expression and communication are based on representations such as language and imagery, the process of learning is enhanced by broadening the types of instructional messages students and faculty can exchange (Dede, 1996).

Below is a list of devices, media, and virtual contexts enabled by sophisticated information technologies, along with the author's estimates of a conservative timeframe for their technological and economic feasibility. Even though no financial or technical barriers exist, note that many current capabilities are not yet widely used instructionally. University scholarship rapidly employs new knowledge-sharing media, but pedagogical and assessment practices in higher education are slow to alter.

Functionality	Uses	Time Frame
Hypermedia (nonlinear traversal of multimedia information)	Interlinking of diverse subject matter; easier conceptual exploration, multiple simultaneous representations for learning	Current
Cognitive audit trails (automatic recording of user actions)	Support for finding patterns of sub-optimal performance	Current
Computer-supported cooperative work (design, problem solving, decision support)	Facilitation of team task performance	Current
Intelligent tutors and	Models of embedded	Current

coaches for restricted domains	expertise for greater individualization	
Optical-disc systems with multiple read/ write and mixed-media capabilities	Support of large databases; cheap secondary storage; shared distributed virtual environments	Current
Standardization of computer and telecommunications protocols	Easy connectivity, compatibility; lower costs	Current
User-specific, limited-vocabulary voice recognition	Restricted natural language input	Current
High quality voice synthesis	Auditory natural language output	Current
Sophisticated authoring and user interface management systems	Easier development of applications; reduced time for novices to master a program	Current
Widespread high-bandwidth fiber-optic networks	Massive real time data exchange	3-5 years
Fusion of computers, telecommunications	Easy interconnection; universal “information appliances”	3-5 years
Information “utilities” (synthesis of media, databases, and communications)	Access to integrated sources of data and tools for assimilation	3-5 years
Microworlds (limited, alternate	Experience in applying theoretical information	3-5 years

realities with user control over rules)	in practical situations	
Semi-intelligent computational agents embedded in applications	Support for user-defined independent actions	5-7 years
Advanced manipulatory input devices (e.g., gesture gloves with tactile feedback)	Mimetic learning which builds on real world experience	5-7 years
Artificial Realities (immersive, multisensory virtual worlds)	Intensely motivating simulation and virtual experience	7-10 years
"Information appliance" performance equivalent to current supercomputers	Sufficient power for simultaneous advanced functionalities	7-10 years
Consciousness sensors (input of user biofeedback into computer)	Monitoring of mood, state of mind	7-10 years
Artifacts with embedded semi-intelligence and wireless interconnections	Inclusion of smart devices in real world settings	2010+

Later in this chapter, images of future learning situations will illustrate how these capabilities might be applied at various levels of schooling, shaping the students who enter higher education and altering the nature of colleges and universities.

The important issue for university instruction is not the availability and affordability of sophisticated computers and telecommunications, but the ways these devices enable powerful learning situations that aid students in extracting meaning out of complexity. New forms of representation (e.g., interactive models that utilize visualization and other means of making abstractions tangible and sensory) make possible a broader, more powerful repertoire of pedagogical strategies. Also, emerging interactive media empower novel types of learning experiences; for example, interpersonal interactions across networks can lead to the formation of virtual communities. As described in the chapter on emerging approaches to learning, the innovative kinds of pedagogy enabled by these novel media make possible evolving university instruction beyond synchronous, group, presentation-centered forms of education, beyond conventional "teaching-by-telling" and "learning-by-listening."

Below, "distributed learning" is discussed as a new form of interaction enabled by advanced information technologies and as a conceptual framework that could guide the evolution of higher education. To illustrate the many possible variants of distributed learning, vignettes (images of plausible futures) are depicted that exemplify how applying this framework might reshape teaching, learning, and the organization of educational institutions. The objective of these vignettes is not to detail blueprints of an unalterable future, but instead to show the range of possibilities enabled by emerging interactive media and the consequences—desirable and undesirable—that may flow from their application in pre-college and higher education settings. Such visions suggest decisions that academicians should make today to explore the potential of these technologies while minimizing unintended and negative outcomes of their use.

Distributed Learning

The conceptual framework underlying the visions of higher education's future presented in this chapter is "distributed learning": educational activities orchestrated via information technology across classrooms, workplaces, homes, and community settings and based on a mixture of presentational and "constructivist" (guided inquiry, collaborative learning, mentoring) pedagogies. Recent advances in "groupware" and experiential simulation enable guided, collaborative inquiry-based learning even though students are in different locations and often are not online at the same time. With the aid of tele-mentors, students can create, share, and master knowledge about authentic real-world problems. Through a mixture of emerging instructional media, learners and educators can engage in synchronous or asynchronous interaction: face-to-face or in disembodied fashion or as an "avatar" expressing an alternate form of individual identity. Instruction can be distributed across space, across time, and across multiple interactive media.

Below is a vignette that illustrates the types of distributed learning elementary school students might routinely experience before they attend high school and college—if our society were to extensively implement *current* information technologies for educational purposes (Dede, 1998).

"Take a deep breath," Maria told her mother, "then blow it out into the balloon." Deftly, as soon as her mother had finished, Maria used a plastic clamp to pinch the neck of the special balloon, then measured its circumference. "All done, Mama!" she said, writing down the number in her notebook. Her mother sneezed, then sank back on the coach with a smile of approval. Even though her sinuses ached—and that deep breath had not helped—she enjoyed helping Maria with her daily homework. After all, participating in the allergy study project not only involved her child more deeply in school, but also subsidized the Web-TV box that provided the family access to sports and entertainment websites. Maria was navigating to the appropriate site, then logging her mother's lung-capacity figure into the national database. Her little brother watched, fascinated by the colored visualizations displaying the complex ecological, meteorological, and pollution factors that predicted today's likely allergic responses in Maria's region of the city.

Maria's teacher, Ms. Grosvenor, was also sighing out a deep breath at that moment, but not into a balloon. While eating a Ho-Ho for breakfast, she was using her home computer to access a different part of the allergy study website, a section with guidance for teachers about how to cover today's classroom lesson on regional flora. Her preservice education a decade ago had provided some background in ecology, but—now that fifth grade students were mastering material she had not learned until the end of high school—Ms. Grosvenor frequently used the website to update her knowledge about allergenic plants. Sometimes the sophisticated multi-level model scientists and doctors were developing, made possible by micro-regional data supplied by learners all across the country, made her head ache for reasons other than sinuses! On the other hand, at least the students were quite involved in this set of science activities. Discussions in the "Teachers' Forum" of the website reaffirmed her own feeling that most teachers would rather have the small hassle of keeping up with new ideas than the constant struggle of trying to motivate students to learn boring lessons.

At the same time, in her elementary school's computer Lab, Consuela was threading her way through a complex maze. Of course, the maze was not in the Lab, but in the "Narnia" MUVE (a text-based Multi-User Virtual Environment developed around the stories by C.S. Lewis). Her classmates and fellow adventurers Joe and Fernando were "with" her, utilizing their Web-TV connections at their homes, as was her mentor, a small bear named Oliver (in reality, a high school senior interested in mythology who assumed a Pooh-like "avatar" in the virtual world of the MUVE). Mr. Curtis, the school principal, watched bemused from the doorway. How different things were in 2009, he thought, students scattered across grade levels and dispersed across the city, yet all together in a shared, fantasy-based learning environment a full hour before school even starts! (The school building opened at the crack of dawn to enable lab-based Web use by learners like Consuela, whose family had no access at home.)

"The extra effort is worth it," thought Mr. Curtis. Seven years into the technology initiative, student motivation was high (increased attendance, learners involved outside of school hours), and parents were impressed by the complex material and sophisticated skills their children were mastering. Even standardized test scores—which measured only a fraction of what was really happening—were rising. Most important, young girls such as Consuela were more involved with school. Because of their culture, Hispanic girls had been very reluctant to approach adult authority figures, like teachers--but the MUVE had altered that by providing a "costume party" environment in which, wearing the "mask" of technology, children's and teachers' avatars could mingle without cultural constraints. "I wonder what this generation will be like in high school—or college!" mused Mr. Curtis.

This vignette depicts how some students who are silent and passive in classroom settings may "find their voice" in an interactive medium. Even the best instructor, expert in facilitating discussion, knows that a substantial percentage of students will "lurk" in group face-to-face interactions. These learners are awake and listening, but do not become actively involved unless forced to do so—and then relapse into silent observation. Such pupils may be shy, prefer time to reflect before answering, or feel at a disadvantage because of gender, race, physical appearance, disabilities, or a lack of linguistic fluency. That face-to-face learning may be "half-a-loaf" for some participants helps to explain why many residential college students have chosen to take advantage of their campus's distance education offerings, much to the surprise of the faculty, who see face-to face-teaching as the best possible medium. Beyond the simplistic visual/auditory/kinesthetic/symbolic categorization of learning styles, much research is needed to understand the opportunities that emerging interactive media offer students disenfranchised by face-to-face interaction (Dede, 1999a).

Given the earlier vignette depicting elementary pupils engaged in distributed learning, in a decade what types of educational technologies might some secondary students experience before college? (Dede, 1995a)

In a rural area about sixty miles from the city, high school student Karen sits down at her information appliance (notepad device with the power of today's supercomputers), currently configured as an electronics diagnosis/repair training device. When sign-in is complete, the device acknowledges her readiness to begin Lesson Twelve: Teamed Correction of Malfunctioning Communications Sensor. Her "knowbot" (machine-based agent) establishes a telecommunications link to Phil, her partner in the exercise, who is sitting at a similar device in his suburban home thirty miles away. "Why did I have the bad luck to get paired with this clown?" she thinks, noting the vacant expression on his face in the video window. "He probably spent last night partying instead of preparing for the lesson." A favorite saying of the community college faculty member to whom she is apprenticed flits through her mind, "The effectiveness of computer-supported cooperative work can be severely limited by the team's weakest member."

"Let's begin," says Karen decisively. "I'll put on the DataArm (a manipulatory device that incorporates force-feedback to its user) to find and remove the faulty component. You use the hypertext database to locate the appropriate repair procedure." Without giving Phil time to reply, she puts on her head-mounted display, brings up an AR (artificial reality) depicting the interior of a TransStar communications groundstation receiver, and begins strapping on the DataArm. The reality-engine's meshing of computer graphics and video images presents a near-perfect simulation, although moving too rapidly causes objects to blur slightly. Slowly, she grasps a microwrench with her "hand" on the screen and begins to loosen the first fastener on the amplifier's cover. Haptic feedback from the DataArm to her hand completes the illusion, and she winces as she realizes the bolt is rusty and will be difficult to remove without breaking.

Dr. Dunleavy, the community college vocational educator who serves as mentor to Karen and Phil, virtually monitors Karen's avatar as she struggles with opening the simulated device. He notes approvingly that she seems as comfortable with the physical, hands-on parts of the job as well as the intellectual analysis; both sets of skills are important in a future engineer. "Documenting a strong recommendation for Advanced Placement college credit via the Educational Testing Service will be easy in her case," he thinks, "but Phil is in danger of failing this unit. Maybe Ms. Tunbridge (the TransStar communications repair expert also serving as mentor for this experience) will offer him a job right out of high school, giving him some time to mature before he heads for college."

At his information appliance, Phil calls up the hypertext database for Electronics Repair. On the screen, a multicolored, three-dimensional network of interconnections appears and begins to rotate slowly. Just looking at the knowledge web makes his eyes hurt. Since the screen resolution is excellent, he suspects that a lack of sleep is the culprit. "Lesson Twelve," says Phil slowly, and a trail is highlighted in the network. He begins to skim through a sea of stories, harvesting metaphors and analogies, while simultaneously monitoring a small window in the upper left-hand corner of the screen that is beginning to fill with data from the diagnostic sensors on Karen's DataArm.

Several paragraphs of text are displayed at the bottom of the screen, ignored by Phil. Since his learning style is predominantly visual and auditory rather than symbolic, he listens to the web as it vocalizes this textual material, watching a graphical pointer maneuver over a blueprint. Three figurines gesture near the top of the display, indicating that they know related stories. On the right hand side of the monitor, an interest-based browser shows index entries grouped by issue, hardware configuration, and functional system.

Traversing the network at the speed at which Karen is working is difficult, given his lack of sleep, and he makes several missteps. "Knowledge Base," says Phil slowly, "infer what the optical memory chip does to the three-dimensional quantum well superlattice." The voice of his knowbot suddenly responds, "You seem to be assuming a sensor flaw when the amplifier may be the problem." "Shut up!" thinks Phil, hitting the cut-off switch. He then groans as he visualizes his knowbot feeding the cognitive audit trail of his actions into the workstations of his mentors. He cannot terminate those incriminating records and cringes when he imagines his mentor's "avatar" delivering another lecture on his shortcomings. Mentally, Phil begins phrasing an elaborate excuse to send his instructors via email at the termination of the lesson.

For her part, Karen is exasperatedly watching the window on her AR display in which Phil's diagnostic responses should be appearing. "He's hopeless," she thinks.

Her knowbot's "consciousness sensor" (a biofeedback link that monitors user attention and mood) interrupts with a warning: "Your blood pressure is rising rapidly; this could trigger a migraine headache."   "Why," says Karen with a sigh, "couldn't I have lived in the age when students learned from textbooks?"

In a decade, entering college students who have experienced the types of distributed learning technologies described thus far are unlikely to be impressed by large lecture classes, multiple choice tests, and sage-on-the-stage relationships with faculty. This will drive profound changes in higher education toward distributed learning.

Within a couple decades, "distance education" may be an obsolete concept, as may the term "face-to-face education." Instead, all instruction within college and university settings may be some balance between classroom-based and distance-based learning interactions, determined by the subject matter, student population, and educational objectives. Such distributed learning demonstrates to students that education is integral to all aspects of life—not just schooling. This instructional approach also can build partnerships for learning among stakeholders in education (e.g., faculty and employers).

In the long run, distributed learning can potentially conserve scarce financial resources by maximizing the educational usage of information devices (televisions, computers, telephones, videogames) in homes and workplaces. In addition, distributed learning enables shifts in the pattern of universities' investments. Less money is needed for physical infrastructure—buildings, parking lots—and more resources can go into ways of creating a virtual community for creating, sharing, and mastering knowledge.

Human and Organizational Challenges in Implementing Distributed Learning

Central to the effective utilization of emerging educational technologies via distributed learning is developing a reflective understanding of how each interactive medium shapes the cognitive, affective, and social interactions of participants. The creation, sharing, and mastery of knowledge is not simply an intellectual exercise; the emotional and psychosocial dimensions of learning are very important as well. Emerging interactive media enable an extraordinary range of cognitive, affective, and social "affordances" (enhancements of human capabilities) of great power for distributed learning—while at the same time also potentially limiting students' and instructors' expression and communication.

Much study is needed to develop the new kinds of rhetoric necessary to make these emerging media effective for learning, as well as to design distributed learning environments appropriate to specific groups of learners for particular types of content and a given set of educational goals. While a great deal is known about instructional design in classroom settings to facilitate affective and social interactions, many emerging media are so new that little is understood about the emotional and collaborative affordances they provide—and lack.

The vignette below presents a deliberately dystopian protrayal of how emerging information technologies, if unreflectively applied, could enrich some aspects of higher education while also exacerbating some of its weaknesses (Dede, 1995b). This depicts the daily routine of a faculty member a couple decades from now and illustrates some potential implications for colleges and universities of artifacts with embedded intelligence. [The ideas and situations in this image of the future draw heavily on a scenario from Weiser (1991).] The purpose of this image of the future is not to predict how colleges and universities will evolve, but instead to illustrate the types of smart devices that will permeate society in the future and some instructional capabilities that they will enable.

Vesper is driving to work through heavy rush hour traffic. She is a faculty member in computational engineering at a university located far from her home in the suburbs. Despite the long drive, the position was irresistible because the campus is noted for its usage of advanced networking technologies. She glances in the *foreview mirror* to check the traffic. {Commuters' automobiles are hooked into a large network that uses data sent by cars and highway sensors to monitor and coordinate the flow of traffic. The "foreview mirror" presents a graphic display of what is happening up to five miles in front of her car on Vesper's planned route to work.} Noticing a traffic slowdown ahead, Vesper taps a button on the steering column to check for alternate routes that might be faster. A moment later, she cancels the request for rerouting as the foreview mirror reveals the green icon of a food shop on a side street near the next exit from the freeway. The foreview mirror helps her to find a parking space quickly, and she orders a cup of coffee while waiting for the traffic jam to clear.

While drinking her coffee, Vesper calls up some work on the screen of her *information appliance*. {This device has the approximate processing power of supercomputers a decade from now and is about the size of a notepad. It is linked via wireless networking and fiberoptic cable to a large web of other information applicances, including those at Vesper's campus.} The university's diagnostic expert system for debugging prototype ULSI designs can handle the routine misconceptions typical of most senior engineering majors, but occasionally is stumped by an unusual faulty procedure that some learner has misgeneralized. {At this point in history, a computer program trained to mimic human experts can handle many routine aspects of evaluating student performance, but complex assessments still require human involvement.} Vesper has an uncanny ability to recognize exotic error patterns by quickly scanning a complex schematic. She diagnoses three sets of student misgeneralizations before resuming her trip to school. Her knowbot (semi-intelligent agent) automatically sends this new "bug collection" to the national database on design misconceptions to be entered into its statistical records. Her knowbot also forwards her diagnoses to the university's expert system on ULSI design, which incorporates the new bugs into its knowledge base and begins preparing intelligent tutoring systems modules to correct those particular errors. Later that day, this instructional material will be forwarded to the appropriate learners' notepads to provide individualized remediation.

As Vesper walks into the engineering complex on campus, her personalized *identity tab* registers her presence on the university's Net of security sensors. {In a clip-on badge displaying her picture and name, a small device is embedded that broadcasts information about Vesper's movements. Such an identity screening procedure is part of the university's security system. In this future world, these elaborate precautions have unfortunately become necessary .} A moment later, the machines in her office initiate a log-in cycle in preparation for her arrival. She realizes that she has left her car unlocked, but does not bother to retrace her steps; from her office, she can access the network to lock her car via a remote command.

As Vesper gets to her desk, the *telltale* by her door begins blinking, indicating that the department's espresso machine has finished brewing her cafe au lait. {A telltale is a remote signaling device that can be triggered to blink or make a sound, advising people in its vicinity of some event happening elsewhere.} Vesper drinks a cup of cafe au lait every morning on arriving. She heads down the hall to get the coffee; the espresso maker's brew will be much better than the vile stuff she had consumed at the food shop. On returning to her office, she instructs her knowbot to remind her not to stop there again. A copy of her evaluation is automatically forwarded to the food shop's manager and to the local consumer ratings magazine.

In the hour before class, as her senior students “arrive,” they congregate in their various engineering labs to work on projects for their exhibition portfolios. (Of course, many of these students are not physically located on Vesper’s campus; instead the facilities used by her students are geographically scattered all over the world, linked via broadband communications.) Vesper will “join” them in about half an hour to begin instruction. She takes a break from viewing her videomail to “surveil” their activities on their individual notepads. Valerie is still dallying too long before getting down to work; Vesper will have to speak with her. Ricardo has not arrived at his engineering complex, but no message has come in to indicate why he is later than usual.

Skimming an engineering education journal, she notices a case study that resembles a problem student in one of her colleague's classes. His apprentice appears to have a rare type of learning disability that interferes with developing a spatial sense of geometric relationships, an important skill in his branch of engineering. Vesper sends an excerpt from the article to her colleague's machine with voice-mail appended explaining its significance. She tends to avoid videomail, even though its greater bandwidth empowers more subtle shades of meaning. It is too much trouble to assume a professional demeanor just to send a simple message. The knowbot in her journal-reading application notes that she found the article useful and reinforces the pattern recognizers that triggered its selection.

A small light on the edge of Vesper's glasses begins blinking. A phone call is coming in; must be from someone not on the network. "Activate," says Vesper (the only word her glasses can recognize). A voice begins speaking in her ear; Ricardo's girlfriend, informing her that he is sick again. With a sigh, Vesper makes a note to prepare hardcopy homework that will be sent off by snailmail—what a hassle! She will be glad when all governments finally recognize that home access to basic network services is a fundamental right, even if that does mean subsidizing subscriptions for the poor.

Across campus, two graduates of local high schools are waiting their turn for individual consultations at the Admissions Office. Both have equivalent, above-average transcripts and want to attend college in this city, but Nick has no money to offer beyond the minimum subsidy this State provides, while Elizabeth has $150,000 from her parents to use on her postsecondary education. Nick will be offered four years of predominantly large-group classes, most from other higher education institutions taught by lecture/discussion across distance or via computer-based training software. However, he will have some local seminar classes in his junior and senior year, this campus will arrange for an unpaid internship with a regional employer., and he will receive a degree from this university. In contrast, due to her financial contribution, Elizabeth will be offered mostly small-group classes, predominantly local (although many fellow students in those classes will attend across distance, as in Vesper's instruction). Elizabeth will also have a tele-mentoring relationship with a nationally recognized expert in whatever major she chooses and a senior-year apprenticeship guaranteed with one of her five top choices of employers.

Down the hall, the university's president chairs a meeting on their forthcoming re-accreditation. Since the last accreditation a decade ago, major shifts have occurred. Many students who enroll in this university's courses live outside this region and will graduate from other colleges, while most local students take the majority of their courses across distance from other institutions, then have these counted toward their graduation from here. Due to excellent teaching, strong scholarly reputations, and distributed collaborations with industry, the faculty are better paid and have smaller classes—they command high fees in the competitive national market for distance course enrollments. However, determining "institutional quality" in this situation is a little confusing to the group preparing for accreditation: How does one describe this type of distributed virtual organization? Who counts as students? faculty?

Before walking down to the lab to join her students, Vesper decides to have a conversation with her colleague Dimitri. Both received notifications last week about next year's salary. Vesper got a 15% raise because the spirited bidding nationally for the limited distance-based enrollments in her classes drove up the university's revenue and thus the teaching part of her wages. Unfortunately, the opposite happened to Dimitri; his salary dropped 10%, as comparable faculty across the country showed greater increases in research visibility, student performance outcomes, and learners' ratings of teaching performance. All this led to reduced fees being paid by prospective applicants to his classes and lower wages for him. Vesper is trying to cheer up Dimitri by suggesting ways he can reverse this trend. Being this subject to the laws of supply and demand is upsetting to both instructors, but that is the price of progress…

As discussed earlier, this vignette's purpose is not to suggest that Vesper's world is the only possible future for higher education, but instead to illustrate the types of smart devices that will permeate society in the future and the human and organizational capabilities—and challenges—they enable.

Many readers may find the above vignette unattractive from an affective and ethical perspective. Vesper's environment may seem implausible—why would a person choose to live in such a machine-centered environment, with so little direct human contact—but how would today's world of cellular phones, facsimiles, electronic mail, voicemail, and streaming audio and video have seemed two decades ago? Further, in this hypothetical future the power of interactive learning media has resulted in a market-driven, survival-of-the-fittest climate in higher education (comparable to what has happened in many other economic sectors). Also, the vignette deliberately incorporates a high level of surveillance; instruction is individualized by monitoring students' activities and intervening if these do not match some predetermined pattern.

From my perspective as an educator, such an evolution would be unattractive. However, I deliberately incorporated some dystopian aspects into this vignette—including concerns about equitable educational services in an era of greater access via distributed learning—to underscore that the design of powerful technologies must be carefully considered to avoid unfortunate side-effects. Of course, artifacts with embedded intelligence could be incorporated into education without the types of behavioristic manipulation which I have crafted into this future depiction. Whether the market-driven and inegalitarian impacts can be avoided is less clear. However, since other distributed learning vignettes in this chapter are optimistic portrayals, interjecting some pessimism into this vision seemed a good way to balance the scenarios and remove any “gee whiz” veneer on how emerging technologies will influence higher education.

Conclusion

The National Science Foundation (NSF) is currently studying how distributed learning communities aid in conducting research (Dede, 1999b). Two years ago, NSF instituted a new multidisciplinary funding program to examine the potential of emerging information technologies in fostering “Knowledge and Distributed Intelligence” (KDI). This initiative [http://www.ehr.nsf.gov/kdi/default.htm] was prompted by fundamental shifts that new interactive media are creating in the process of science. Scientists are moving away from investigative strategies based on reading others’ research results in journal publications as a means of informing and guiding one’s own scholarship. Instead, many scientists are engaged in virtual communities for creating, sharing, and mastering knowledge: exchanging real-time data, deliberating alternative interpretations of that information, using collaboration tools to discuss the meaning of findings, and collectively evolving new conceptual frameworks.

NSF calls this process “knowledge networking” and is funding a series of KDI investigations to study these virtual communities both in the context of science and as a generalizable process that could enhance many forms of reflective human activity. Through knowledge networking, an emergent intelligence appears in which the virtual community develops a communal memory and wisdom that surpasses the individual contributions of each participant. NSF is supporting studies of this process through its “Learning and Intelligent Systems” (LIS) initiative within KDI.

For example, Marcia Linn at the University of California-Berkeley is leading Project SCOPE: Science Controversies On-line: Partnerships in Education. This project promotes knowledge networking among scientists and learners exploring current scientific controversies that connect to citizens’ interests (such as evidence of life on Mars). The project’s research combines expertise in natural science, pedagogy, technology, and classroom instruction from the University of California-Berkeley, the University of Washington, and the American Association for the Advancement of Science’s *Science* magazine. Both national and international partners are involved in the distributed learning experiences. The investigators are creating new media as needed and using existing knowledge-sharing applications (for example, Linn's Knowledge Integration Environment [KIE] tools [http://www.kie.berkeley.edu/KIE/software/descriptions.html]).

Both knowledge networking and emergent intelligence are important new capabilities that can transform the learning process at every level of education. Knowledge networking involves creating a community of mind. Through sharing disparate data and diverse perspectives, a group develops an evolving understanding of a complex topic. Over time, the group's conception of the issues continually expands and deepens, at times broadening the range of fields and experiences seen as relevant. During these times, the membership of a networking community grows to include participants who bring new perspectives and backgrounds. Thus, a knowledge network is in longitudinal flux as an ever-larger cast of members redefines how to conceptualize the topic; this involves a constant collective acculturation into new ways of thinking and knowing. For example, in the context of improving higher education, the participants in a knowledge network might be faculty, administrators, parents, taxpayers, employers, politicians, researchers, accreditation agencies, and other policymakers—each bringing differing perspectives and knowledge across multiple educational settings. Communal learning is at the core of the knowledge networking process.

This type of interaction is becoming routine in university scholarship, but unfortunately shifts in instruction lag far behind. For that matter, no one talks about “distance scholarship,” but the academy is puzzled about how to handle “distance education,” incorrectly seeing it as some minor variant of conventional teaching rather than as an exemplification of the much larger process of knowledge networking now reshaping civilization. In a few years, high performance computing and communications will make knowledge utilities, virtual communities, shared synthetic environments, and sensory immersion as routine a part of everyday existence as the telephone, television, radio, and newspaper are today.

In this future, keeping a balance between virtual interaction and direct interchange is important (Dede, 1996). Technology-mediated communication and experience supplement, but do not replace, immediate involvement in real settings; thoughtful and caring participation is vital for making these new capabilities truly valuable in complementing face-to-face interactions. How a medium shapes its users, as well as its message, is a central issue in understanding the transformation of distance education into distributed learning. The telephone creates conversationalists; the book develops imaginers, who can conjure a rich mental image from sparse symbols on a printed page. Much of television programming induces passive observers; other shows, such as Sesame Street and public affairs programs, can spark users' enthusiasm and enrich their perspectives. As we move beyond naive “information superhighway” concepts to envision the potential impacts of knowledge networking and distributed learning, society will face powerful new interactive media capable not only of great good, but also misuse.

The most significant influence on the evolution of higher education will not be the technical development of more powerful devices, but the professional development of wise designers, educators, and learners.

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