ISSUES IN EDUCATION RESEARCH

PROBLEMS and POSSIBILITIES

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CHAPTER FIFTEEN

New Media Communications Forums for Improving Education Research and Practice

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What have been the early experiences in education and other disciplines with new computer-mediated technologies for the construction, submission, review, and publication of scholarly works? What new forms of scholarly communication are appearing that may contribute to knowledge about education in the future? How might the new communications technologies be shaped in ways that will improve what many see as the inexcusably weak links now present between education research and educational practice?

Scholarly publication in education today is predominantly print based. Yet the emerging interactive forms of publication, made possible by the explosive commercialization and democratization of access to the Internet and the World Wide Web, have tremendous potential for changing fundamentally how education research is conceived, conducted, authored, and critically responded to by its audiences. The new media forums could, moreover, serve to improve the understanding and practice of education, particularly in conjunction with design experiments in education settings, in which innovative practices are designed, implemented, assessed, and continuously adapted in dynamic partnership

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between social scientists and educators. The incorporation of primary audio-video data of classroom cases, interviews, and other educational artifacts in works published on-line could help to bridge the jargon gap between researchers and practitioners, linking them in a unified knowledge network. It even seems possible that as access to the Internet becomes more widespread, the fingertip availability of new media communications platforms such as the World Wide Web could advance a much-needed integration of the perspectives of education researchers, practitioners, and other education stakeholders in research inquiries.

The Internet and the Web are increasingly viewed as tools for capturing and composing digital multimedia documents, electronic publishing, collaborative reporting, and multiuser virtual environments, including virtual worlds. This chapter examines the use of these tools in a decontextualized manner, by situating them in specific pioneering efforts to transform scholarly communication in other disciplines and showing how the new media may fundamentally change every phase in the life cycle of education research. Those practicing disciplines such as physics, molecular biology, computer science, mathematics, and the humanities are further along than those in the field of education in thinking through the implications of these emerging genres, and their experiences and consequences for education research are explored here. The chapter provides a selective review of leading-edge developments in electronic journals, multimedia case presentations, moderated on-line conferences, and other more dynamic publication forums that engage significant audience participation. It concludes with a set of high-priority directions for developing new communications media to support education research, additionally addressing the requirements for creating a two-way, "live," and ever-evolving communications infrastructure for educational improvement.

Because the prospect of a rapidly changing role for the educator in the education research enterprise is a central focus of this chapter and because what I think about most is education research concerning cognition and instruction, teaching and instructional discourse, curriculum, and technology, much of my discussion and speculation concern these subareas. Specialists in history, sociology, or administrative studies will undoubtedly have different perspectives.

THE CURRENT STATE OF SCHOLARLY PUBLICATION IN EDUCATION

Education research in its various facets is an extraordinarily broad-ranging enterprise. The comprehensive Scholarly Societies Project of the University of Waterloo, which analyzes the history of scholarly publication, makes the case that most journals—the predominant means for publishing and communicating

research findings—have developed from the activities of scholarly societies. As of October 1998 the project has documented eighty-six societies devoted to the study of aspects of education (see http://www.lib.uwaterloo.ca/society/education_soc.html), ranging from subject matter teaching, as in physics, mathematics, and foreign languages, to the different levels of education, to curriculum and technology. For K–12 education and teacher education, an informative annotated list of 426 current education journals has been developed and is maintained by the staffs of the University of Wisconsin–Madison Instructional Materials Center and the Kansas State University Libraries (http:/wwwsoemadison.wisc.edu/IMC/journals/anno_AB.html).

What observations can one make about the production, publication, and consumption of scholarly research in education today? First, virtually all of education research is published exclusively in linear print media, and little use is made of more dynamic media such as animations, videos, or sound in communicating the processes and results of research. This is true even though a great deal of the primary data that are collected in education studies includes observations of classroom interactions and interviews with students, teachers, and other participants in education (Berliner and Calfee, 1996). In addition there has been little effort within the education research community to capitalize on the advantages of live links to other documents offered by current hypertext and hypermedia systems made broadly accessible through Web standards. The peer-reviewed electronic journal *Education Policy Analysis Archives*, edited by Eugene V. Glass, is one of the few scholarly electronic publishing efforts in the field of education (http://olam.ed.asu.epaa/). Twenty other electronic journals dealing with education are listed in the Education Electronic Library (http://wwwlib.waterloo.ca/discipline/education/journals.html), but with the exception of the 1996-initiated and award-winning *Journal of Interactive Media in Education* (*JIME*), they are on-line text-based journals. (The pioneering case of *JIME* is discussed later in this chapter.)

Second, the time lag between the write-up of education research results and journal publication is lengthy, often a year or more. After submission of the article, the peer review and author revision phase often takes six to eighteen months to complete. Although the period from acceptance to publication can be as short as about a year in journals like the *Educational Researcher*, the usual time cycle is another twelve to eighteen months (Denning and Rous, 1995). With electronic publishing, on the other hand, near-instantaneous sharing of research results is possible (although Internet-based communication is posing its own set of challenges to the economics of scholarly publishing, copyright protection, access, and the function of peer review).

Third, educators, the front-line agents for educational change, rarely read education research articles. A common lament among education researchers is

that research knowledge of "what works" is not put into practice as broadly as "it should be" by educators (Kaestle, 1993). Complementary complaints among educational practitioners are that the information they want or need is hard to find, they have no time to read education research reports, and even if they did, such articles tend to be jargon filled, speaking to them in terms or in discourse frameworks that they cannot readily understand or put into practice (Kennedy, 1983).

Fourth, few educational practitioners produce reflective documents, in any media, about their teaching experiences that could help shape education research topics and strategies for improved learning. Absent experience with a readership for their works, it is a major challenge for teachers to learn how to write for others about what they are learning from their practices so that others may benefit. Yet the wisdom and learning that are embodied in classroom processes, orchestrated by teachers through their conceptual lenses, has extraordinary potential for producing actionable knowledge in education research. A strategy developed over the past several decades has been for scholars in education to work collaboratively with teachers to support their authorship of such reflective stories (Ruopp, Gal, Drayton, and Pfister, 1993).

These four features of education research could all change significantly as a function of the integration of new communications media in forums concerning research inquiry and educational practice and learning. The recent proliferation of experimentation in and commercialization of Web-based electronic publishing could reduce the time lag for education research publication, as it is doing in other fields. But even more to the point, widespread media-rich documentation of life in the classroom, and its interpretations by teachers as well as researchers, could altogether transform the properties of scholarly publication, the accessibility of research to educators, and the production of reflective documents by practitioners. Before considering these possibilities, it is worthwhile to highlight some distinctive aspects of education research inquiry.

THE NATURE AND PURPOSES OF INQUIRY IN EDUCATION RESEARCH

As one of the primary generative functions of a society, well articulated by John Dewey and by developmentalists such as Erik Erikson, education is an exceptionally vital enterprise. Education fundamentally involves values and norms; it seeks through its activities to guide human development in the directions valued by the communities that educational enterprises serve (see also Moll and Diaz, 1987). The normative goals of education—what a society seeks to achieve

through its activities—essentially involves renewal. In this sense, education is at once conservative—looking to the past and learning from it—and "subversive" and futuristic, second-guessing the needs of the possible worlds ahead and readying learners to adapt to them creatively and successfully over a lifetime of major changes in society, culture, and environment. Education research has the dual purpose of improving our understanding of the functioning of different levels of activity in education systems (such as conceptual change in physics for learners in a specific instructional environment or teacher development in the context of a reform-oriented school) and guiding improvements in practices (for example, in learning environment design or in administrative supports that facilitate effective reforms). Research in education thus has special properties as a field of inquiry and reporting; it is a fundamentally different kind of enterprise from research in physics or molecular biology.

There have been cycles of optimism and pessimism since the early twentieth century about the prospects for improving education practice through research, and recent years have seen a renewed call for researchers to show the practical value of their studies as well as to develop more collaborative methods involving scientists and educators (Huberman, 1989; McLaughlin, 1987). In response, there has been a growing use of design experiments to try innovations in the classroom and to assess new learning environments (Brown, 1992; Collins, 1992; Gomez, Fishman, and Pea, 1998; Hawkins and Collins, forthcoming; Salomon, 1995). But there are major issues of how to scale up such design experiments beyond a handful of schools.

Putting new curricula into daily practice is a hard task, and many curriculum researchers and reformers have seen the hoped-for reforms targeted by their innovations become "lethal mutations" when inappropriately interpreted in the classroom. Educators, in turn, have been frustrated with whole-cloth admonitions to transform their daily teaching practices with the latest research innovations. Although design experiments offer a promising approach to resolving these difficulties, their crucial feature—the collaborative engagement of researchers and educators in finding a common ground for advancing best educational practices around a reform agenda and set of reform strategies—presupposes an intimacy of communicative exchange that has escaped realization in the large. Why is this the case?

All curricula, and in particular new reform curricula, undergo significant adaptation during implementation in the classroom (Berman and McLaughlin, 1978). Curricula do not serve simply as scripts for transforming practice. Educators continue the design process for curricula in how they tailor learning activities, goals, and affiliated assessments in order to meet local circumstances. Such tailoring is challenging.

In addition, teachers work in a system, so that the tailoring process, although mainly centered in the classroom, is not limited to teachers using the curricula

but expands to other members of the school community, including teacher colleagues, administrators, parents, and students. Curricular implementation thus offers up occasions, if the right kinds of support are provided, for educators to reflect on practice, consider new ideas, construct new understandings about practice, and reconstruct practice (Cohen and Ball, 1990).

The implications of this line of argument are significant for reflecting on design requirements for new communication forums for education research and practice. Educators and others involved in the enterprise could be better supported in the activities of tailoring new curricula to local contexts. Opportunities for this, and for sharing the successes and failures in the processes involved, should be explicitly built into new communication forums for education in the decade ahead. Media-rich annotations of curricula and other resources by education stakeholders, particularly teachers, could advance a form of "living curriculum," in which one's own experiences, and the plans and learnings of others, are shared and adapted within a broad-based, knowledge-building community. As yet we know little about how to do this.

One vehicle for beginning such experimentation would be an ever-evolving interlinked database, served by an open network, in which teachers could reflect on their tailoring experiences by posting on the Internet cases, from which others might learn. Like the personalized Web pages of educational resources that teachers have collected and shared with other educators, access to easy-to-use case development tools around curricular and other classroom practices could open up major venues for interteacher learning networks.

REPRESENTATIONAL MEDIA AND EDUCATION INQUIRY

Here I roughly delineate different phases in the life cycle of education research. These phases are useful in showing how representational media, and the properties of communication systems in which they are used, may lead to changes in the production and use of education research knowledge. In turn, I consider how traditional practices of conceiving, conducting, analyzing, authoring, and responding to and using education research may become transformed by these new media (and in some cases *should* become transformed because of the special normative properties of the field). Of course, in actual practice, these phases of the life cycle of education research are not strictly linear but are often iterative and embedded in structure.

I take for granted that different forms of representation may highlight or obscure aspects of the world they aim to represent (Mills and Pea, 1989). This position continues a line of argument well articulated by Kant and philosophers of the human sciences such as Giambattista Vico in the early 18th century, Johann Herder in the mid-18th century, and Wilhelm Dilthey's 19th-century

writings on the history of culture, but most identified with the philosopher Nelson Goodman in writings such as *Ways of Worldmaking*. I apply this notion to the representations that we scholars of education use in our research publications (also see writings in the sociology of science by Latour and Woolgar, 1986; Lynch and Woolgar, 1990). The questions that arise, and the strategies that are used to pursue inquiry, often vary considerably across representational systems. For example, with respect to representing a physical system comprising an optical bench with a light source and a lens, very different properties are useful in different representations about, for instance, a photograph, a ray-tracing diagram embodying laws of geometrical optics, an algebraic equation for the depicted physical system, a written description of the scene, or an interactive simulation model of the optical bench physical system (Pea, 1992). Similarly, in presenting qualitative case studies of teaching and learning, there are distinctive strengths and weaknesses in the use of stories, time-coded observations of different categories of behavior, and edited videoclips of actual classroom interactions, depending on the aims of the inquiry. Questions about which representational forms to choose for depicting the results of scholarly investigations in education are not only about what it means to use the different forms, say video, in research to display data; they are "at a more fundamental level about what it means to do research," as Elliot Eisner rightly points out (1997, p. 5).

It is important to recognize that the alternative forms of data representation that have accompanied the proliferation of qualitative studies and their affiliated methods (from ethnography to discourse analysis) in education research over the past two decades are as much political as scientific contributions to the understanding of education. The same is likely to be true of representational revolutions in new communication forums for education research.

Conceiving Education Research with New Media

Education research is conceived and planned today largely by researchers outside the day-to-day concerns of educators. In its questions, methodologies, and reporting styles, such research tends to be driven by the professional standards of scholarly inquiry of the societies and journals of its constituent fields. The role of new media has been minimal thus far in transforming these traditional practices, although Nicholas Burbules and Chip Bruce (1995) illustrate, in their *Education Researcher* article "This Is Not a Paper," how the growing use of e-mail, listservs, bulletin boards, and newsgroups has started to transform the boundaries between correspondence and scholarly publication, personal and professional interchange, works in progress, and final publications and to challenge many fundamental assumptions about the production and ownership of intellectual works now largely resident in peer-reviewed print publications.

A listserv, a common Internet discourse medium, is simply an e-mail distribution list. For making announcements to sizable groups, or organizing discussion around a topic for a community of interest, it is a particularly valuable tool (for AERA's divisional listservs, see http://aera.net).

Yet in comparison with many scientific fields, education researchers engage in a small amount of electronic conferencing, and few experiments are under way to redefine the genre of scholarly communication. As of October 30, 1998, the *Directory of Scholarly and Professional E-Conferences* lists 265 different ongoing electronic conferences concerned with different facets of education research (http://wwwn2h2.com/kovaks/), and many of these are affiliated with divisions of the American Education Research Association (AERA). The AERA listserv moderated by Gene Glass (bitlistserv.aera) is listed as having fifty-three hundred readers, averaging twenty-seven messages contributed per day. Compare this to the much larger and far more active listservs devoted to topics as esoteric as vampires and furry-animal erotica.

This minimalist role of new media in the conceptualization of education research could change quickly if the gateways of communication *from* teachers in classrooms *to* the traditionally university-based education research community were opened up. As educators have begun to explore the internetworked world of information from their classrooms, the flow of learning could move from the classroom to the researcher, reversing the more traditional one-way transmission flow from theory and research into practice (Suppes, 1978).

Although unlikely to be sufficient in themselves, several preliminary conditions are necessary for such changes to occur. The first is broad-scale networking of classrooms, so that teachers have regular access to the Internet, preferably from home and school. The second is the existence of virtual "social places"—electronic hallways and other "places" in which discourse about practices among teachers (and perhaps for a research-interested community) could be conducted and well supported with communications tools, shared work spaces, and other resources. The third is simple-to-use tools for educators to author "cases" and publish them on the Internet. Cases, commonly employed in other fields such as business, law, and medicine, could provide a new kind of communication vehicle for teachers to share their experiences with colleagues and learn from one another through cumulative, reflective discourse about them.

Broad-Scale Networking of Classrooms. How realistic is it to expect that all classrooms in the United States will have access to the Internet and to Web sites for learning and teaching, and will thereby become richer resources for inquiries in the education research community? Until the past several years, the trend had been for schools to be internetworked, if at all, primarily for administrative purposes (Newman, Bernstein, and Reese, 1992). This is perhaps not all that surprising, since teachers are among the few professionals in our society who do

not have a telephone for their work space, and an Internet connection to computers located in a classroom requires either a telephone (for dial-up modem access) or a faster connection, typically provided by an Internet service provider.

But rapid developments are occurring in internetworking classrooms and schools. As one example, during the first NetDay in 1996, over 250,000 volunteers helped wire 50,000 classrooms across the United States. Studies by the National Center for Education Statistics, U.S. Department of Education (NCES 1997, 1998), and the CEO Forum on Education and Technology (1997) provide complementary findings of an explosive growth in school and classroom Internet connectivity in the past two years, and school plans illustrate the same general fast growth trend. The proportion of schools that are able to access the Internet increased from 35 percent in 1994 to 78 percent in fall 1997, according to the National Center for Educational Statistics (NCES, 1998). A 1998 *Education Week* survey (Oct. 1) of all 96,000 public schools, conducted from February 1998 to June 1998, indicated that 85 percent have Internet access (compared to 76 percent for cable TV), but only 30 percent of schools (although 49 percent of districts) have a wide area network connection rather than modem dial-up (*EW,* Nov. 10, 1997). The proportion of actual classrooms from which teachers and learners can access the Internet is far smaller but also rapidly growing. The 1998 NCES survey showed only 9 percent of classrooms connected to the Internet in 1995, 14 percent in 1996, but a surge to 44 percent of classrooms in early 1998. Nationwide, the number of students per multimedia computer (including a sound card and CD-ROM drive) is still very spare, at thirteen to one (*EW,* Oct. 1, 1998). For comparative purposes, it is worth mentioning that a survey by the National Council for Accreditation of Teacher Education (1997) of 744 schools of education in May 1996 showed only 45 percent of faculty members using interactive instructional tools in their teaching and only 42 percent of education schools having at least one classroom wired for the Internet (Zehr, 1997). The current definition of a high-tech school—Internet access, local area network within the school, and better-than-average access for students to multimedia computers—is met by only 18 percent of schools nationwide, according to *Education Week* (Nov. 10, 1997).

Also, since 1997, IBM has been sponsoring the largest K–12 Internet project of our times. As part of the American School Directory (ASD) project, which is a collaboration of IBM K–12 Education, Apple Computer, Vanderbilt University, and Computers for Education, IBM is providing a free Internet Web site to all 106,000 K–2 schools and free e-mail accounts to every teacher and student in the United States. The objective of this project, announced in December 1996, is to provide an American School Directory (http://wwwasd.com/) so that teachers may access new resources for curriculum development, parents and other community members may connect to information on activities in their schools, and students may use free e-mail and other Internet resources for learning.

In another large program, Pacific Bell is spending $100 million between 1994 and 2000 for Education First, providing free ISDN (Integrated Systems Digital Network) lines to schools (much faster than today's dial-up modems) in California and on-site teacher technology training, Web site development, and related support.

In short, although networking all the classrooms in the United States and establishing Internet service does not by itself make for network-ready teachers, keen and able to put the Web's diverse resources to work for teaching and learning, as an essential condition of a new model for forging communication linkages between educational professionals and education researchers, it is well on its way to becoming widespread, and, I would expect eventually, universal.

Virtual Social Places for Teacher Networking. Current estimates are that only one in five teachers uses a computer regularly for teaching (CEO Forum, 1997; NCES, 1997). Could the appropriation curve be accelerated if teacher professional development organizations and teachers were to use the technology itself to learn more about how to integrate computing into their work practices?

Since 1996 SRI International's Center for Technology in Learning has been engaged in partnership with K–12 teacher professional development (TPD) organizations devoted to science education reform. Together they are developing, operating, and studying an easy-to-learn, on-line teacher professional development service called TAPPED IN (http://wwwtappedin.sri.com) (Schlager, Schank, and Godard, 1997). Using federal and private foundation grants to build this virtual learning community, the affiliated organizations—including the Lawrence Hall of Science in Berkeley, the Science Education Academy of the Bay Area, the Life Lab Science Curriculum Program, the California Science Project, and the Bay Area School Reform Collaborative—help underwrite the expenses of teacher participation and SRI's development of some of the TAPPED IN functions and services to meet their specific needs.

TAPPED IN integrates the best of current Internet communications tools, such as e-mail, listservs, Web pages, and newsgroups, into a Web-based graphical, multiuser virtual environment that simulates and extends face-to-face, real-time collaborative learning and mentoring situations. Geographically distributed teachers can meet and learn from one another by diverse levels of interactivity in the simulated graphical environment of a "conference center building" (a virtual place). Participants select an office in the extensible floor plans of TAPPED IN and bring in various informational resources for joint review or mentoring with colleagues and others (such as text and graphic "overheads," class notes or plans, articles, and pointers to Web pages). Whiteboards in meeting spaces may be written on, erased, and saved as meeting archives, along with textual discourse that participants contribute to a meeting. If TAPPED IN participants are using Web browsers supporting Java Telnet, they can collaboratively browse

Web pages together. Those who are sharing views on the same Web page can tour other sites together and make written commentaries as they go, which may be archived in TAPPED IN as a record of their meeting's activities.

TAPPED IN provides the technical infrastructure to support the TPD agendas and activities of each individual organization with which a teacher may be involved (such as workshops). Individual teachers may also "wander the halls" of the TAPPED IN virtual spaces, encountering other teachers, teacher professional developers, or researchers with whom they may share their experiences. They can thus use the collective TPD resources of the diverse set of participants TPD organizations beyond those of their "home" TPD provider.

Users of TAPPED IN can evolve the facilities and resources in this on-line center to suit their needs. They may link images (including three-dimensional objects using Virtual Reality Modeling Language) (http://wwwvrmlsite.com/), text, or Web pages via Internet links to virtual objects in the virtual space of the TAPPED IN on-line conference center. For example, the Lawrence Hall of Science maintains a number of virtual "rooms" around a reception area in TAPPED IN. One of these is the GEMS Room (Great Explorations in Math and Science). GEMS is a leading worldwide resource for supporting activity-based science and mathematics learning. It provides guidelines for how teachers without formal background in math and science can nonetheless use recommended everyday materials and foster student-guided discovery inquiry-based learning.

Although there are other network-supported teacher professional development forums, the TAPPED IN project illustrates the potential of new kinds of virtual places for filling crucial needs in the teachers' lifelong learning process. Schlager, Schank, and Godard's ongoing research examines the forms and experiences of teacher participation and learning that are found in a communication-rich, multiuser virtual environment of this kind.

More general developments of relevance for education and learning are occurring with "virtual world" technologies. It has been argued that the future of the Internet is a "social place," not a "digital library" (Curtis, Sonin, and Zaritsky, 1995). Patterns of usage for the Internet and systems such as America and CompuServe indicate that hundreds of millions of user hours are being spent on-line in chat rooms and other social places, in which users may connect through their computers to have textual conversations in real time. Inspired by these results, a number of Silicon Valley companies are seeking to provide the infrastructure to take the social desires of Internet users to the next level. These innovators have created tools for building and interacting in a variety of virtual worlds. Users can select or design "avatars"—graphical representations of "self" in cyberspace—and the objects and places in their interactive environments. They may then interact with others who happen to be connected to particular virtual world services (for example, The Palace, Worlds Away). Over two million downloads of The Palace virtual world software have been used to cre-

ate and populate over a thousand virtual worlds, including some devoted to education and learning. Unlike present-day MUD (Multi-User Dungeons) and MOO (MUD, Object-Oriented), future virtual world users will be able to form large virtual communities and grow vast interconnected neighborhoods of their own design, which can scale nearly infinitely because of their distributed network architectural design.

In a specific education application of these ideas, Robert Kozma and Ruth Lang at SRI International are building "virtual places for collaborative science simulations." They are using undergraduate chemistry learning and precollege science teacher professional development as their domains and asking what specialized virtual places, resources, and capabilities are needed to support the social role and cognitive strategies involved in science learning. Based on their initial work, they are integrating client-server, multiuser virtual environment (MUVE) technologies like TAPPED IN (see Schlager et al., 1997) to provide diverse types of virtual places such as project rooms, lab benches, auditoriums, and digital libraries, with peer-to-peer synchronous multimedia collaboration technology. Such peer-to-peer collaboration will provide audio channels and simultaneous control and viewing of software applications such as simulations and tools for creating and manipulating other media used in learning and teaching (dynamic graphs, animations, equations, data tables).

Case Authoring Tools for Teachers to Share Their Experiences. In design experiments and other participatory design methods, the knowledge that teachers acquire, and their perspectives on such issues as what it takes to tailor an innovative project-based earth sciences curriculum to their inner-city social context and learning community, is not easily shared. Yet such sharing is likely an important factor in whether innovations in educational practice will scale up. The education research community is far too small to be directly involved in supporting such reflective processes among the roughly three million K–12 U.S. teachers. Are there ways that researchers could extend their reach through the use of new kinds of communications tools?

One need is for teachers to express more promptly their new learnings from the experience of tailoring innovations in context. Case tools can do this. Several prototypes already exist, including JavaCap and other case library tools from Georgia Institute of Technology's Edutech Institute (Kolodner and others, 1997; Shabo, Nagel, Guzdial, and Kolodner, 1997, pp. 241–249). Support to teachers who are learning to use reflective multimedia documents is provided in the work of Ricki Goldman-Segall (1990, 1998). Her *Learning Constellations* software provides multimedia ethnographic materials about grade 4–5 learners and their computer-rich classroom learning situations, so that different audiences can build connections among, and offer reflective commentaries about, these resources. For the purpose of communicating practices with preservice

teachers about how to implement reform-oriented elementary mathematics teaching, Deborah Ball and Magdalene Lampert at the University of Michigan have also used hypermedia systems to create layers of interpretive annotations of videos of classroom teaching (see their chapter in this volume).

By means of case-based tools, teachers would be able to represent an experienced situation. Indexes would provide access to the cases by a user community seeking to learn from them (Ferguson, Bareiss, Birnbaum, and Osgood, 1992; Kolodner and others, 1997). Key research issues in using cases for supporting teachers' learning are how to select cases, how to identify which aspects of cases are crucial to facilitate learning, and what indexes will enable teachers to find the best cases for meeting the demands of a new problem they are facing. A common case architecture (Kolodner, 1993) is useful in this regard:

- The problem or situation the case is about
- The alternative means for addressing the issues in the problem or situation
- The results from carrying out the means used for addressing the issue
- An explanation for why the outcome occurred, whether expected or not (lessons learned)

Then, as Kolodner and others (1997) state, "While solving a problem or reasoning, a reasoner navigates to appropriate cases in the case library by using its indexed links. A case, told as a story about what happened in some situation, may suggest a way to solve a new problem, an issue that needs to be addressed, or a problem that might be expected to arise if some type of solution is put in place" (p. 151).

The importance of cases and stories to make education research more relevant to teachers' practices has also been highlighted (Carter, 1993; Connelly and Clandinin, 1990). Perhaps education research could become more relevant if researchers viewed the classroom as teachers view it, in their own terms (Kennedy, 1997). For example, one might imagine an extensive case library where teachers, working in diverse school settings with learners of different grade levels or abilities, would provide cases concerning how they went about appropriating a new technology or curricular innovation, such as the Internet project-based learning resources and teaching pedagogy in the atmospheric and earth sciences provided by the CoVis Project (Pea and others, 1997). Authored by teachers (perhaps with initial support from education researchers), the cases would summarize important aspects of their experience that they believe other teachers would find useful in the process of adapting these innovations to their own classrooms. Indexed at a useful level of detail, such a case library would help teachers who are new to those innovations more effectively manage their

appropriation of these innovations. Cases from the field could perhaps serve as effective substitutes for, or complements to, the more traditional teacher professional development workshops at which such innovations are introduced, after which teachers are sent on their way to implement them locally. What specific form these tools would need to take, and in tandem with what types of personal and professional support for their use among the teaching community, are issues that must be resolved.

A working example from preservice teacher professional development suggests the utility of multimedia cases, even if they are not authored by teachers per se. Developed at the University of Michigan (Krajcik and others, in press), CaPPs (Casebook about Project Practices) provides a CD-ROM–based multimedia library of video clips and affiliated commentary that teachers can use for addressing their questions about project-based science (PBS). CaPPs is structured according to an exploration of teachers' questions concerning five key features of PBS: the use of driving questions, artifacts, collaboration, investigations, and technology. The concept is that new teachers can acquire a practical view of how PBS looks in real classrooms—and what its challenges and key properties are—by viewing video clips of experienced PBS teachers. These clips have annotations from researchers, other teachers, and the video-recorded teachers' reflections.

In summary, with the fulfillment of certain requisite conditions that are coming to fruition in new tools and practices in education research, new computing and communications tools may lead to sizable changes in how education research is conceived—changes that could provide a more substantial voice for practitioners than they now enjoy and changes in other phases of education research, particularly audience involvement in making formal research knowledge into actionable knowledge.

Conducting Education Research with New Media Tools

What implications do new communications media have for data representation issues (Eisner, 1997) in education research? (Fetterman, 1998, provides for a basic introductory article on kinds of computer and Internet resources for education research and instruction.) Although there is quite a lot of practical knowledge required to master the art of capturing good audio-video records in the noisy environments of classrooms (Roschelle and Zaritsky, 1995; Curtis, Sonin, and Zaritsky, 1997), the benefits of having accessible replayable records for research and instructional purposes (as for teacher professional development) have been long recognized. With the drop in costs for professional-quality recording and editing devices, inexpensive and easy-to-use computer video- and sound-editing tools, and the increased accessibility of digital cameras and video cameras that allow video and sound files to be imported directly into computer-based

documents (http://wwwncsa.uiuc.edu/Cyberia/DVE/FusionDVE/html/future_developments.html),many researchers have begun to use new media in their education research.

A particular advantage of the new digital videorecorders is no loss of quality across generations of video editing. An area of emerging interest for researchers is computer-enhanced logging, coding, and retrieval of these audio-video records (for general issues, see Roschelle, Pea, and Trigg, 1990; SIGCHI, 1989; MacKay, 1995, pp. 138–145). Scanners also make it possible to assemble in one integrated medium a digital portfolio of students' work that may include paper lesson assignments, essays, videoclips of presentations and discussions, and other learning and teaching artifacts.

Analyzing Education Research Data with New Media

Once the researcher collects education research data, data interpretation and data analysis ensue. It is uncommon for the traditional subjects of such research—students, teachers, administrators, or others—to participate in the analysis of education research data. But the social science research community has begun to appreciate the value of having diverse perspectives on the patterns of data seen from learning and teaching settings (Brettell, 1993; Jordan and Henderson, 1993).

Some work involves teachers in watching videotapes of their own instruction or that of their peers and relies importantly on the perspectives that the participants in educational practice have on the meaning and coherence of their teaching activities. It is not too hard to imagine such involvement on a much larger scale (Sheingold and Frederiksen, 1995). What if participants in education research studies were provided with opportunities for making sense of the data that researchers have collected? What if they were allowed a voice in authoring the meaning of what transpires from a first-person rather than third-person perspective? This scenario does not eliminate the voice of the education researcher, but it opens up new lines of understanding for a broader audience. It is likely that a teacher-practitioner may find the categories of experience represented in other teachers' rendering of the meaning of their own practice more accessible than the theoretical categories common in the interpretive frames of the education researcher.

Authoring Education Research with New Media

Authoring education research articles for publication in a linear print medium today has much in common with authoring publications in earlier centuries. Paper (or more recently computer files) provides the inscriptional medium, and through a series of drafts, reviews (informal by colleagues and formal once submitted), and revisions, a final version is produced that is then archived in a paper journal or book. Publication of the research write-up may be individual or collaborative.

How is the nature of the work practices involved in this authoring process changing with the integration of communications technologies to serve old functions and with the invention of new forms that take advantages of the new properties of these media? I briefly describe a few of the ways, including changes in collaborative authoring, changes in media used to represent information in publications, and changes in the interrelationships of publications and their accessibility in an on-line medium (see also Burbules, 1998).

Collaborative Authoring. Consider the authoring involved in the composition of a report of education research. Collaborative research among education researchers is common, even across disparate empirical boundaries (for example, cognitive science, curriculum development, and teacher learning). As many scholars have pointed out, the networked communications recently made possible by the Internet over the past several decades have already provided new supports for such collaborative research and authoring in many scientific disciplines (Kiesler and Sproull, 1991), including education research to a small extent (Burbules and Bruce, 1995). As Peter Denning and Bernard Rous (1995) noted for computer science publications, "Authors are increasingly viewing their works as 'living on the Web.' . . . They see networks as new opportunities for collaborative authoring and for dynamic documents that incorporate other documents by link rather than by direct copying." More generally, the importance of distributed collaborative networks of researchers—dubbed "collaboratories" (NRC, 1993; Wulf, 1989)—has been heralded as the new organizational form for scientific research (Finholt and Olson, 1997; Johnston and Sachs, 1997).

At the most basic level, an author working in a location different from a coauthor's can work sequentially on a report on education research and, via electronic networks, nearly instantly send along the draft document for new work to be carried out by the collaborator. While undeniably important, this baton passing is a primitive form of networked collaborative authoring. Programs such as Microsoft Word now have group-writing revision facilities that provide support for many authors to propose revisions to a single document, which can then all be considered and accepted, rejected, or modified in a write-through pass by a lead writer. Also, screen-sharing programs such as Farallon's Timbuktu and shared whiteboards over the Internet such as those provided by TeamWave (http://wwwteamwave.com) make it possible for several researchers to work together at a distance on a text, using a parallel telephone channel or Internet telephone connection to mediate who has cursor control as a document is collaboratively elaborated in real time.

Multimedia Documents. Over the past several years, developments in software paradigms, such as Apple Computer's Quicktime for storing and replaying audio, video and animations in digital form, and object-oriented programming

and component software, have made it possible to integrate graphical, video, and audio data files in text documents. Initially possible on stand-alone computers, these functionalities are now available over the World Wide Web, so that multimedia Web pages can be posted on one's Web site as documents that can be interacted with by users throughout the world across heterogeneous computer platforms (MacIntosh, PC, UNIX, NT). A great deal of experimentation in diverse fields of scholarship and teaching is evident as university faculty members, other researchers, and practitioners in the worlds of business and the arts explore the new genre for communicating the production of knowledge or works in their respective fields.

These developments are foundational. As Jay Bolter (1991) argued in his analysis of the history of writing, *Writing Space*, the representational media available for expressing, manipulating, and sharing the results of our thinking have had over the millennia a pivotal influence on what kinds of content were expressed, on who was able to benefit from these writings, and in how representational competencies were acquired (see also Lanham, 1993; Birkerts, 1994; Peek and Newby, 1996; Snyder, 1997). What might be possible and desirable in education research with multimedia documents?

Mitchell Nathan and others (1994) carried out some experimentation with the prospect of interactive multimedia journal (IMMJ) articles in education research. They argue for the utility of multimedia representations in capturing key aspects of educational contexts and of learning–teaching interactions (CTGV, 1994), as well as highlighting some risks and obstacles to using rich media for communicating the results of scholarly research in education. They do not include in their discussion hyperlinking resources within an interactive multimedia journal article, as is practiced in other fields, but restrict their consideration to a linear article model of a scientific report.

Among the IMMJ capabilities that Nathan and others (1994) consider to be important for communicating education research are the depiction of dynamic and interactive instructional materials and how they are used in instructional settings as well as concrete examples of how their use is received by learners. Summing up these properties, they argue that IMMJ articles can lead to more accurate mental models of instructional interventions among readers of these documents, provide valuable instantiations of abstract technical language used by education researchers (because actual classroom practices are depicted), and support more inclusive communication of research results to diverse audiences, including teachers, parents, school administrators, and community members.

Nathan and others (1994) also highlight some important limitations of IMMJ articles as they imagine them. One of these is the selective nature of video-recording in classrooms, which, although also present in other data collection activities, has the added burden of the video medium. Unlike textual descriptions, even when edited, such video data tend to convey a strong sense for the viewer of

direct experience with the primary phenomena that are documented. A second issue is the integrity of video data that are being reported, where the concern is time sequence or time compression alterations distorting "the way it was." Another limitation they point to is the ethical dilemma posed when the visual identity, even without the name or location, of the participants in the research is revealed. Although this may not be problematic when the demonstrated effects of research interventions are profoundly beneficial, it could be damaging for the individuals involved when poor teaching practices or learners' faulty patterns of reasoning (important in the text-based educational research literature) are exposed. On this latter issue, they argue that only "very brief images that capture the global nature of the classroom intervention are generally safe to show because they do not center on any one person, do not reveal any particular behaviors that can be considered negatively, and still provide the reader of an IMMJ with a good feel for the execution of an instructional intervention" (p. 271). They recommend that individual teacher or student video depictions not be used until standards are agreed on for ensuring anonymity of video-based data.

The *Journal of Interactive Media in Education* (*JIME*), launched in September 1996 (http://www-jimeopen.ac.uk/jime/index.html), is the first electronic journal in education experimenting with issues of interactive media within its publications, for it fully integrates *JIME* articles with a structured (frame-based) Web discussion space to foster new models of scholarly practice (Sumner and Shum, 1996). For this purpose, *JIME* has adapted the National Center for Supercomputing Applications' HyperNews system so that reviewers may publish commentaries on articles under review linked to specific sections, figures and demonstrations, other reviewers' comments, and other resources considered relevant to the article by the commentator. An article is submitted, and reviewers and authors debate the submission, then open up the process to peer review. An edited version of this discussion is archived with the final publication, and subscribed authors and other interested parties receive e-mail announcing new postings about the article.

The editorial statement for *JIME* argues that a design field like interactive educational media must be able to present and critique its designs for scholarly progress to be appropriately conducted. To this end, *JIME* also allows authors to include interactive media demonstrations of instructional systems and users' uses of them in articles (in Macromedia Shockwave format). Thus far, they have not included the ethically challenging media of human-centered videos of instructional interactions.

Audience Involvement in Education Research with New Media

An important outcome of new media for authoring education research reports involves another major change: that the traditional audiences of a researcher's

text can become much more interactively involved in the creation of the document and even in what counts as a document.

Unlike the cases I will consider of e-publishing in physics and in the cognitive sciences, the field of education research has the distinctive problem of needing to relate much more intimately to the phenomena of study—the participants in teaching and learning. Teachers, educational leaders, educational policymakers, and even parents are not only prospective audiences for education research but potential contributors to it. Education studies for a century have sought to illuminate and improve the scientific understanding of education, learning, and teaching. These other education stakeholders have a special insight into the day-to-day sites in which the theoretical knowledge and findings of educational inquiry could be applied; they also have the potential ability to tap new problems and solutions for long-standing concerns that should be shared with the education research community.

One of the most pronounced differences that has begun to emerge between print media and new interactive media is the relationship between author and reader. The boundaries between author and reader are familiar in the print medium. A work is authored, submitted to a publisher, and reviewed, revised for publication, and printed in quantities expected to be sufficient for projected sales. The reader buys and reads the work. Little communication transpires between reader and author.

In the emerging genre of new media on the Web, these relationships are much more intimate and are coming to change authors' and audiences' behaviors and expectations. Authors often now serve as hosts of America Online real-time chats with hundreds of participants concerning their print media or on-line works. Commentaries on an author's works are hyperlinked to drafts or archival versions of their publications on-line, and an author may be notified by e-mail when new commentaries appear.

Consider one preeminent example in some detail. The preprint phase in the history of scientific manuscripts is well known for its importance in the sociology of science. Traditionally a small number of close affiliates of a scientist or scientific team—an "invisible college"—are sent early draft versions of a scientific paper for remarks before the paper is formally submitted for publication. The preprints of papers actually submitted but not yet accepted for publication present another stage in the evolution of a scientific publication. Finally, there is the penultimate stage, when a scientific paper has been accepted by a journal, and the scientist or scientific team elects to send around the accepted manuscript to their scientific colleagues before it appears in print.

The preprint phase of this process is under radical transformation with the advent of the World Wide Web, most evidently in physics but also in many other fields. Widespread reliance on the uses of electronic preprints by scientists is commonplace in some fields of the hard sciences (http://xxxlanl.gov/)

and computer science (Association of Computing Machinery with its 80,000 members). Consider the famous case of the "e-print archives" at Los Alamos.

In August 1991, an electronic database of physics prepublications was initiated for a small community of under two hundred people, designated "hep-th" (for High Energy Physics, Theory). Within months, this Los Alamos physics e-print archive had expanded to over a thousand users, and by August 1994 it was used regularly by over thirty-six hundred (Ginsparg, 1994) of the world's estimated forty-five thousand physicists. The technical infrastructure for this system is automated, including the process of submitting preprints, and indexing their titles, authors, and abstracts. The archive may be accessed from the Web, FTP, or by e-mail. A crucial aspect of the e-print database is that it serves the needs of researchers who are presenting formal materials that they would ordinarily publish by conventional means in journals; the documents are not like usenet newsgroups or bulletin board systems. One of the most interesting results of this effort has been that in some subfields of physics, these on-line electronic archives rapidly became the primary means for researchers to communicate ongoing research, supplanting print journals (Ginsparg, 1994). As of October 1998, the http server statistics for the e-print archives indicate that roughly 500,000 connections are made to the server each week (http://xxxlanl.gov/cgi-bin/show_weekly_graph), with more than 2,200 new submissions during July 1997 alone (http://xxxlanl.gov/cgi-bin/show_monthly_submissions).

What are some of the other properties of e-Print archives that have become useful to its affiliated research communities? Besides the two-way submission and downloading of communications, authors can establish, and readers can follow, hyperlinked references within papers and use a password scheme that enables the author to transfer paper ownership to a journal or other party and to provide addenda. The history of revisions of a paper is also often saved in the archives for scholarly review.

Paul Ginsparg (1996) specifically notes that these archives do not constitute an electronic journal:

> The majority of authors continue to submit in parallel with conventional journal submission to take advantage of immediate distribution (and de facto precedence claim), and subsequent revisions frequently benefit as much or more from direct reader feedback as from the conventional referee process. Some authors feel more comfortable submitting only after a conventional refereeing process, with an attached "to appear in" comment, still taking advantage of both the advance distribution and archival availability. Certain journals have begun to accept the archive identifier as the electronic submission itself, and conduct their editor/referee interactions as well by means of the version retrieved from the archive. *Astrophysical Journal Letters* (published by the American Astronomical Society) actively encourages authors of accepted letters to place the "preprint" of the final accepted version in the astro-ph archive. The identifying

number is then used to add a link directly to the astro-ph from a Web page with a list of letters that have been accepted but not yet published. *Physical Review D* has similarly begun to add such link information to its own Web pages, and in addition uploads directly to the archive information concerning papers "to appear," and later their published status—the information is then available whenever users search the archive listings or browse abstracts. Better coordination with the existing archives could provide similar immediate benefits to readers of other APS journals.

Knowledge Networking: Electronic Journals and On-line Forums

Much of the preceding section on new communication forums for different phases of the education research process is speculative in nature. Yet as the Los Alamos physics e-Print archives illustrate, disciplines besides education are further along in thinking through the consequences of new media for their genre of scholarly communication. What are the specific forms of new scholarly communication that are appearing, such as electronic journals, multimedia case presentations, moderated on-line conferences, and audience commentaries on materials made available in Web sites? What have been the early experiences in the disciplines, including education, with new media forums for the construction, submission, review, and publication of scholarly works?

Elsevier Science's debut of its electronic journal *New Astronomy* includes an illustration of a theoretical model that is a video simulation of binary pulsars, with two stars rotating around each other, evolving as one sucks up matter from the other, then explodes in a supernova. Springer-Verlag's *Journal of Molecular Modeling* is fully electronic, includes dynamic three-dimensional illustrations, and is on the Web. The next section includes a selective review of the leading-edge developments in electronic journals and other more dynamic publication forums that engage significant audience participation.

Three different forms of electronic journals have been distinguished: on-line, CD-ROM, and networked (Woodward and McKnight, 1995). Many of the features commonly recommended as beneficial to researchers, such as hyperlinked referencing to other papers, are not as well achieved in CD-ROM–only solutions to providing electronic journals.

Science, technology, and medicine (STM) are vibrant disciplines for the proliferation of peer-reviewed on-line journals (e-journals), with many hundreds of examples in place. Hitchcock and others (1998) estimate 3,000–5,000 peer-reviewed e-journals in all fields are available worldwide. Steve Hitchcock found three primary sources for STM electronic journals: commercial publishers, nonprofit learned societies, and research institutions such as universities (Hitchcock, Carr, and Hall, 1996; also Mogge, 1996). Paper journals for STM disciplines are among the most expensive published, and document users would benefit

considerably from electronic document access (Duranceau, 1995). Roughly half of those specialized, technical journals with typically high development costs (often involving expensive graphics) appeared in 1995, and, of the one hundred or so, close to half required paid subscription to view. Interestingly, nearly all from the university-based on-line journal developers were provided freely to readers (Hitchcock, Carr, and Hall, 1996). This situation may be contrasted with results from a recent study of 125 electronic journals by Harter and Kim (1996), which found that roughly 90 percent of the electronic versions of the journals reviewed—primarily in the social sciences, professions, and humanities, but also in some of the sciences—were available at no cost. Almost all peer-reviewed on-line journals are currently free, with publishers covering costs primarily from paper journal subscriptions or incremental revenues from site licenses paid by institutions from which users log in (Taubes, 1996).

Why have on-line journals exploded onto the scientific scene? As many authors have indicated, there are novel features of electronic publishing that provide a significant value added to the linear print medium—for example:

- Rapid access to disciplinary preprints
- Capacity to publish vast amounts of materials quickly and cheaply
- Searchability
- Hyperlinking to other papers and databases (primarily) and, in principle but rarely in practice, diverse dynamic media (such as animated graphics, video, audio, and interactive programs or simulations)
- Annotation capabilities so that readers may communicate with authors and one another
- Notification services, so that interested readers can be automatically notified by e-mail, discussion lists, or newsgroups when articles appear on-line in which they might have an interest

Perhaps one of the most intriguing findings from the first several years of experience with electronic journals is evidence pointing to the need for reinventing the user experience with the journal article, given the properties of this new publishing medium. In biology, scientists have recognized how electronic databases of three-dimensional graphical molecular structure representations could be made accessible through electronic publishing. And, as Gary Taubes (1996) noted, electronic journals in the sciences are already beginning to offer different forms of reader activity, author preparation requirements, and database interconnections:

> Already a mouse click can take a subscriber from one article to related articles in the same journal, other journals, and resources such as databases of DNA sequences, protein structures, or galaxy images. By offering authors' raw data or

> the software used in the analysis, some of the journals will allow readers to double-check an author's work. . . . And any genes in JBC articles are linked to [GenBank] [GenBank http://wwwncbi.nlm.nih.gov/Web/Genbank/nar.edit.html], a service provided by the NIH's [National Institutes of Health] National Center for Biotechnical Information. Click on the gene, and you can go directly to the DNA sequence, if it exists. From GenBank [GenBank DNA Sequence Database], the NLM's [National Library of Medicine] own database structure allows users to jump in turn to other publications relevant to that sequence.

The Worm Community System (WCS) is an asynchronous collaboration system for the community of molecular biologists studying the nematode worm *Caenorhabditis elegans*, a model organism used for genetic sequencing in the Human Genome Initiative (HGI). The HGI aims to list in open databases the map and location of the full human genome and of other model organisms and to build up links to knowledge and scientific literature over the course of its scientific discoveries. The informatics needs of the HGI called for developments in advanced computing for distributed collaboration (Courteau, 1991; Frenkel, 1991; Pool, 1993) and could serve as an example to inspire the education research community. WCS was developed as a community system in molecular biology, an experiment of the National Science Foundation's National Collaboratory Project, and is often cited as the national model for future science information systems.

The aim of WCS (Schatz, 1991–1992; 1993; Schatz and others, 1996) is to support researchers within this biological research community in finding available knowledge, adding their own knowledge for others' use, and forming research knowledge interrelationships by connecting as well as annotating research entries (hyperlinking). In his design rationale for WCS, Bruce Schatz (1993) argued for the needs among community members for knowledge networks to span formal archival publications and informal "transient folklore."

WCS includes archival data (gene descriptions), physical maps, DNA sequences, cell lists and lineages, formal and informal literature, and analysis software programs. Given the rapidity of knowledge development in this area, and the fact that the diverse user communities for such knowledge (such as biologists specializing in other organisms or subfields of molecular biology) often do not share technical vocabulary (Furnas and others, 1987), WCS developed an algorithmic approach to the automatic generation of a domain-specific thesaurus by analyzing stored documents using externally acquired controlled term (keyword) lists, automatic indexing techniques, and statistics-based cluster analysis algorithms (Chen and Lynch, 1992). The WCS thesaurus that came out of this work captured domain-specific concepts and defines relevance interrelationship values between them, and allowed automatic updating. Then users of a simple browser to access WCS could use their own vocabularies and the semantics-rich thesaurus for finding related concepts.

Such experimentation with knowledge networks is not limited to the sciences but includes the humanities. Since 1985 the Perseus Project (Crane, 1996) has constructed a digital library for studying the ancient world of Archaic and Classical Greece with scholarly resources such as hundreds of Greek texts and translations; philological tools; extensive art catalogues of thousands of vases, sculptures, and other antiquities; and archaeological maps of hundreds of buildings and sites—in addition to color satellite map images annotated with ancient place names. *Thesaurus Florentinus* provides a large digital library of images of restoration under way at the Santa Maria del Fiore in Florence that can be used in different scholarship activities (Friedlander, 1996).

Nonetheless, experience to date (Hitchcock, Carr, and Hall, 1996) suggests that on-line journals have not mushroomed in fields such as computer science that lack a strong preprint culture (unlike physics or mathematics) and do not have important needs for wide distribution of results because others' work depends on them (as in physics).

The behavioral and brain sciences provide an example of advanced experimentation in on-line forums for scholarly communication using these new media. The prominent example of high interactivity between authors and readers is provided in the peer commentary, or "scholarly skywriting," advocated by Steven Harnad (Harnad, 1990, 1991), editor of *The Behavioral and Brain Sciences (BBS)* (see also Mason, 1992; Strangelove and Kovaks, 1992). In 1978, modeled after *Current Anthropology, BBS* began pioneering the publishing genre of "open peer commentary," in which fifteen to twenty-five scholars across specialties and around the world write critical reactions to target articles that are also rigorously peer reviewed, followed by an integrative response from the target article's author(s). Even in its early years, the citation impact of *BBS* was one of the highest in its fields (Drake, 1986).

Harnad now also edits the on-line American Psychological Association–sponsored journal *Psycoloquy* (http://wwwprinceton.edu/~harnad/psyc.html). *Psycoloquy* publishes articles and peer commentary in all areas of psychology, cognitive science, neuroscience, behavioral biology, artificial intelligence, robotics-vision, linguistics, and philosophy. With a combined listserv and usenet subscribership of more than forty thousand, it is a broad-based experiment in publishing refereed brief reports (around forty-five hundred words) of new concepts and results, for which the author wants rapid peer feedback, and of refereed peer feedback on these reports—thus the phrase "scholarly skywriting." Harnad has been a prolific contributor toward conceptualizing the revolutionary potential of the Internet (and more recently the Web) for electronic scholarly publishing (Harnad, 1990, 1991, 1995a, 1995b, 1997). Besides the advantages of more efficient and equitable peer review, Harnad (1995a) argues that the Web's true value for scholarly communications lies in the form of interactive publications that provide open peer commentaries on published and ongoing work.

Harnad's writings on scholarly electronic publishing have evoked considerable animosity in the publishing world and widely favorable reception among many academics (see Okerson and O'Donnell, 1995, for e-mail logs of the debates published as a book). Harnad (1991) argues for making electronic scholarly publications freely available over the Web for "esoteric" fields in the sciences, without "reader-end tolls" since their authors want readers and do not expect payment. But there is a large potential audience for actionable knowledge resulting from education research—millions of teachers and hundreds of millions of parents and community members. Is his argument inappropriately generalized to education research, not such an esoteric field because of its audience size? I do not believe so. Like information about health care and nutrition, information about learning and education is such a fundamental public good that universal access to it should be a priority of the e-publishing world.

Harnad demonstrates that free access is now possible with electronic networks, but until recently the economics of paper publishing have required scholars to make the Faustian bargain with publishers that a price tag will stand between them and their intended audience. Harnad's (1995b) "subversive proposal," issued in the summer of 1994 on the discussion list VPIEJ-L (Virginia Polytechnic Institute, Electronic Journals), is that publishers will not make this transformation themselves, so authors should make all their research papers available as unrefereed preprints over FTP servers (and now the Web) before publishing. His argument continues that when the paper then is accepted for publication in print, the author can replace his or her preprint on the server with the final refereed publication, no one will buy the journal, and publishers will transform their practices so that they charge authors for preparation and distribution but no longer charge readers for access. What scholars really need, he says, "is electronic journals that provide 1) rapid, expert peer-review (for quality control), 2) rapid copy-editing, proofing and publication of accepted articles (for dissemination), 3) rapid, interactive peer commentary (for attribution and desired feedback), and 4) a permanent, universally accessible, searchable and retrievable electronic archive (for access and academic credit)."

Another experiment with on-line forums in electronic journals is the new Elsevier molecular biology journal designed by Nigel Fletcher-Jones, *Gene-COMBIS*, a part of the preeminent journal *Gene* (see Taubes, 1996). In this case, besides hot links to other databases with pharmacological and biomedical information and abstracts and databases of nucleotide and protein sequences, discussion forums are provided that Fletcher-Jones describes as "virtual coffee breaks" akin to the hallway information exchanges at scientific conferences. E-mail from article readers is sent to the editors, who edit the best letters, which are attached on-line to the articles they are about.

While reasonably new in implementation, the widespread provision of Web document annotation tools is being explored in the research programs of several

of the National Science Foundation's Digital Library research centers, including the developments represented in Stanford University's ComMentor (Röscheisen, Mogensen, and Winograd, 1995) and the University of California, Berkeley's multivalent annotation model for digital documents (Phelps and Wilensky, 1997). The model in each case, envisioned half a century ago in the seminal writings of President Roosevelt's science adviser Vannevar Bush (1945), is one in which an ever-expanding web of primary documents and annotations serves to grow an interpretive network of knowledge creation, use, and reflection. At Stanford Research Institute (now SRI International), Douglas Engelbart first implemented Bush's visions of hypertext journals (1975, 1984a, 1984b), and Theodore Nelson (1995, p. 32), the other hypertext pioneer who sought to instantiate Bush's vision, called this property of hyperlinked on-line journals and communication forums (only now widely possible with the Web) "transclusion"—"reuse with original context available, through embedded shared instancing." Since these efforts are only now becoming available, there has not been enough time to do the needed experimentation to find out what form electronic journals should take in different scholarly disciplines. But education research seems a prime candidate for such experimentation, given the special nature of inquiry in the field, which calls for better communication forums between researchers and practitioners than has been permitted by the traditional linear print publishing model.

OPPORTUNITIES AND CHALLENGES

What directions should new communications media take to support the specific needs of education research? And what are some of the critical obstacles to developing a two-way, live, and ever-evolving communications infrastructure for the improvement of education? Two general directions seem to me to provide the greatest breakthrough potential. The first is to pursue the goal of establishing mutually influential two-way communication of insights about learning and teaching—between education scholars as traditionally defined and educational practitioners. The second direction conceives of the Web not as a vast digital library but as a *social place*—one in which fluid social encounters occur routinely among participants in the diverse communities that can contribute to conversations about improving the education enterprise.

On the first direction, the field of education research will need to learn, through invention, field trials, and reflective analyses of experience, what genres of new media reporting work for the research community and for educational practitioners. To find the right form to the genres of reporting and community annotation, and to provide a more open-boundaried dialogue toward the achievement of actionable knowledge, much experimentation is needed in

e-journals and other forums for research communication. As in physics and the brain and behavioral sciences, education researchers will need to take the lead in reinventing the work practices affiliated with their production of knowledge. A crucial part of the work ahead is to foster teacher involvement in these dialogues. It is frequently observed that teachers in the United States spend a greater proportion of their time in teaching than do teachers of other nations (Adelman, 1998; OECD, 1995; see also OTA, 1995), and so any proposals to involve them more integrally in reflective authoring and sharing of their learning about innovations in their classrooms confront the key obstacle of available time. Given the competing demands on their time, teachers need simple case-authoring tools for use in sharing their problems and learning experiences and in tailoring educational curricula and other innovations with one another.

As in the Worm Community System for knowledge networking among molecular biologists and other interested groups, advanced work on indexing, retrieval mechanisms, and meta-data for these cases will also be a priority. Meta-data are simply data about data. In the case of instruction, EduCom has organized a large consortium of organizations, including IBM, the U.S. Department of Defense, and others, to define the kinds of data about instructional management systems that could be used for indexing and retrieving educational materials over the Web. Such meta-data for instructional resources would define their own content domain, their indexing to standards, their age appropriateness, their media types, and so on.

Another challenge on the way to case development and sharing involves tackling successfully the complexities of establishing guidelines for ethical practice in media-rich representations of classroom practice, learning, and teaching events. In the use of primary, media-rich records of educational activities, no simple answers will be forthcoming. The contextualized information that makes a learning situation accessible to an observer of these records also identifies the look, if not the name and location, of the individuals involved. Aspects of the ethics of cyberspace research using on-line textual exchanges have recently been debated in a special number of *Information Society* (Kling, 1996; Thomas, 1996).

As for the second direction—making the Web a social place—I earlier discussed examples of multiuser virtual environments and "virtual worlds" technologies for learning and training. These technologies make it possible to establish neighborhoods, campuses, buildings, and other graphically depicted places to which people may come to meet and conduct various activities. Windows onto these worlds from computer screens may be opened up. Such windows enable geographically remote participants to return to persistent meeting places with persistent objects (such as document files, research lab equipment, portfolios of student work). In these virtual places, they can have real-time communication with others using media including voice, text, graphic, and shared action on simulations or with other applications. The potential benefits of such

developments are wide-ranging, for these environments are readily extensible by users themselves and can be used to form virtual communities of learning around common interests.

As new media communication forums begin to open up the dialogue among the very diverse stakeholders in the education enterprise, issues of the need for universal accessibility to the Web's resources for improving education inevitably and justly arise. There are well-documented differences in computer availability at home and across schools as a function of income and funding levels (*EW*, Nov. 10, 1997). It is certainly a problem of social injustice if perhaps only one-quarter of the parents of school-aged children now are able to engage with knowledge networking about improving education from home over computer channels. Trends toward wiring all classrooms and toward including Internet-linked computers in public libraries and community centers will provide several ways of addressing such inequities. Furthermore, the advent in the past year of television set-top devices such as WebTV that sell for two hundred to three hundred dollars and require a monthly subscription fee of twenty dollars enables consumers to browse the Web over their television without owning a computer.

These trends toward universal access must continue. Many of the virtual world technologies presuppose a desktop computing environment today. But rapid developments in computer component miniaturization, wireless networking, handheld computing, and low-orbiting satellites capable of transmitting streaming audio-video communications suggest that we can anticipate virtual places for anytime and anywhere access to support learning communities within the next two decades. There are many economic and policy issues on the way to providing ubiquitous, fingertip access of new media communication platforms such as the Web, but the social costs of ignoring the need for universal access would be unacceptable.

References

Adelman, N. *Trying to Beat the Clock: Uses of Teacher Professional Development Time in Three Countries.* Washington, D.C.: U.S. Government Printing Office, 1998.

Berliner, D. C., and Calfee, R. C. (eds.). *Handbook of Educational Psychology.* New York: Macmillan, 1996.

Berman, P., and McLaughlin, M. W. *Federal Programs Supporting Educational Change: Vol. 5: Executive Summary.* Santa Monica, Calif.: RAND Corporation, 1975.

Berman, P., and McLaughlin, M. W. *Federal Programs Supporting Educational Change: Implementing and Sustaining Innovation.* Santa Monica, Calif.: RAND Corporation, 1978.

Birkerts, S. *The Gutenberg Elegies: The Fate of Proofreading in an Electronic Age.* New York: Fawcett, 1994.

Bolter, J. *Writing Space: The Computer, Hypertext, and the History of Writing*. Hillsdale, N.J.: Erlbaum, 1991.

Brettell, C. B. (ed.). *When They Read What You Write: The Politics of Ethnography*. New York: Bergin & Garvey, 1993.

Brown, A. "Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings." *Journal of the Learning Sciences*, 1992, *2*(2), 141–178.

Burbules, N. C. "Essay Review: Digital Texts and the Future of Scholarly Writing and Publication." *Journal of Curriculum Studies*, 1998, *30*(1), 105–124.

Burbules, N. C., and Bruce, B. C. "This Is Not a Paper." *Educational Researcher*, 1995, *24*(8), 12–18.

Burbules, N. C., and Callister, T. A., Jr. "Knowledge at the Crossroads: Alternative Futures of Hypertext Environments for Learning." *Educational Theory*, 1996, *46*(1), 23–50.

Bush, V. "As We May Think." *Atlantic Monthly*, July 1945.

[http://www.isg.sfu.ca/~duchier/misc/vbush/vbush-all.shtml]

Carter, K. "The Place of Story in the Study of Teaching and Teacher Education." *Educational Researcher*, 1993, *22*(1), 5–12, 18.

Cognition and Technology Group at Vanderbilt. "From Visual Word Problem Solving to Learning Communities: Changing Conceptions of Cognitive Research." In K. McGilly (ed.), *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice* (pp. 157–200). Cambridge, Mass.: MIT Press, 1994.

CEO Forum on Education and Technology. "The School Technology and Readiness Report: From Pillars to Progress." [www.ceoforum.org]. 1997.

Chen, H., and Lynch, K. J. "Automatic Construction of Networks of Concepts Characterizing Document Databases." *IEEE Transactions on Systems, Man and Cybernetics*, 1992, *22*(5), 885–902.

Cohen, D. K., and Ball, D. L. "Relations Between Policy and Practice: A Commentary." *Educational Evaluation and Policy Analysts*, 1990, *12* (13), 249–256.

Collins, A. "Toward a Design Science of Education." In E. Scanlon and T. O'Shea (eds.), *Proceedings of the NATO Advanced Research Workshop on New Directions in Advanced Educational Technology* (pp. 15–22). New York: Springer-Verlag, 1992.

Connelly, F. M., and Clandinin, D. J. "Stories of Experience and Narrative Inquiry." *Educational Researcher*, 1990, *19*(5), 2–4.

Courteau, J. (1991). "Genome Databases." *Science*, 1991, *254*, 201–207.

Crane, G. "Building a Digital Library: The Perseus Project as a Case Study in the Humanities." In E. A. Fox and G. Marchionini (eds.), *Digital Libraries 1996, Proceedings of the 1st ACM International Conference on Digital Libraries* (pp. 3–10). New York: Association for Computing Machinery, 1996. [http://www.perseus.tufts.edu].

Curtis, D., Sonin, J., and Zaritsky, S. "Digital Video in Education: A Joint Project of NCSA and NCREL." [http://www.ncsa.uiuc.edu/Cyberia/DVE/FusionDVE/html/dve_front_door.html]. 1997.

Curtis, P., and the Jupiter Team. "Not a Highway but a Place: Social Activity on the Net." [http://www.uni-koeln.de/themen/cmc/text/juptno1.txt]. 1995.

Denning, P. J., and Rous, B. "The ACM Electronic Publishing Plan." *Communications of the ACM*, Apr. 1995. [Also see http://info.acm.org/pubs/epub_plan.html.]

Drake, R. A. "Citations to Articles and Commentaries: A Reassessment." *American Psychologist*, 1986, *41*, 324–325.

Duranceau, E. F. (ed.). "The Economics of Electronic Publishing." *Serials Review*, 1995, *21*(1), 77–90.

Editorial Projects in Education. "Technology Counts '97: Schools and Reform in the Information Age." *Education Week*, Nov. 10, 1997 (special issue).

Editorial Projects in Education. "Technology Counts '98: Putting Technology to the Test." *Education Week*, Oct. 1, 1998 (special issue).

Eisner, E. W. (1997). "The Promise and Perils of Alternative Forms of Data Representation." *Educational Researcher*, 1997, *26*(6), 4–10.

Engelbart, D. C. "NLS Teleconferencing Features: The Journal and Shared-Screen Telephoning." *IEEE Catalog No. 75CH0988-6C*. 9tr (pp. 173–176). 1975.

Engelbart, D. C. "Collaboration Support Provisions in AUGMENT." *Proceedings of the 1984 AFIPS Office Automation Conference* (pp. 173–176). Los Angeles, Feb. 20–22, 1984a.

Engelbart, D. C. "Authorship Provisions in AUGMENT." *Proceedings of the 1984 COMPCON Conference* (pp. 465–472). San Francisco, Feb. 27–Mar. 1, 1984b.

Ferguson, W., Bareiss, R., Birnbaum, L., and Osgood, R. "ASK Systems: An Approach to the Realization of Story-Based Teachers." *Journal of the Learning Sciences*, 1992, *2*, 95–134.

Fetterman, D. M. "Webs of Meaning: Computer and Internet Resources for Educational Research and Instruction." *Educational Researcher*, 1998, *27*(3), 22–30.

Finholt, T., and Olson, G. "From Laboratories to Collaboratories: A New Organizational Form for Scientific Collaboratories." *Psychological Science*, 1997, *8*, 28–36.

Frederiksen, J., Sipusic, M., Gamoran, M., and Wolfe, E. *Video Portfolio Assessment*. Emeryville, Calif.: Educational Testing Service, 1992.

Frenkel, K. A. "The Human Genome Project and Informatics." *Communications of the ACM*, 1991, *34*(11), 41–51.

Friedlander, A. "Net Gains for Digital Researchers." *D-Lib* (issue 5). [http://www.ariadne.ac.uk/issue5/digital-researchers/]. 1996.

Furnas, G. W., Landauer, T. K., Gomez, L. M., and Dumais, S. T. "The Vocabulary Problem in Human-System Communication." *Communications of the ACM*, 1987, *30*(11), 964–971.

GenBank DNA Sequence Database. (n.d.). National Center for Biotechnical Information. [http://www.ncbi.nlm.nih.gov/Web/Genbank/nar.edit.html].

Ginsparg, P. "After-Dinner Remarks." APS meeting at LANL (Los Alamos National Laboratory). [http://xxx.lanl.gov/blurb/pg14Oct94.html]. Oct. 1994.

Ginsparg, P. "Los Alamos XXX APS ONLINE." APS News: APS Online (insert), p. 8. [http://xxx.lanl.gov/blurb/sep96news.html]. Nov. 1996.

Goldman-Segall, R. "Learning Constellations: A Multimedia Research Environment for Exploring Children's Theory-Making." In I. Harel (ed.), *Constructionist Learning* (pp. 295–318). Cambridge, Mass.: MIT Media Laboratory, 1990.

Goldman-Segall, R. *Points of Viewing Children's Thinking: A Digital Ethnographer's Journey.* Hillsdale, N.J.: Erlbaum, 1998.

Gomez, L., Fishman, B., and Pea, R. D. "The CoVis Project: Building a Large-Scale Science Education Testbed." *Interactive Learning Environments*, 1998, *6*(1–2), 59–92. (Special issue on telecommunications in education.)

Goodman, N. *Ways of Worldmaking; Based on the Inaugural Series of Immanuel Kant Lectures at Stanford University, 1976.* Hackett Publishing, 1978.

Harnad, S. "Scholarly Skywriting and the Prepublication Continuum of Scientific Inquiry." *Psychological Science*, 1990, *1*, 42–43. [ftp://princeton.edu/pub/harnad/Harnad/harnad90.skywriting].

Harnad, S. "Post-Gutenberg Galaxy: The Fourth Revolution in the Means of Production of Knowledge." *Public-Access Computer Systems Review, 1991, 2*(1), 39–53.

Harnad, S. "Implementing Peer Review on the Net: Scientific Quality Control in Scholarly Electronic Journals." In R. Peek and G. Newby (eds.), *Electronic Publishing Confronts Academia: The Agenda for the Year 2000.* Cambridge, Mass.: MIT Press, 1995a.

Harnad, S. "Universal FTP Archives for Esoteric Science and Scholarship: A Subversive Proposal." In A. Okerson and J. O'Donnell (eds.), *Scholarly Journals at the Crossroads: A Subversive Proposal for Electronic Publishing.* Washington, D.C.: Association of Research Libraries, 1995b. [http://cogsci.soton.ac.uk/~harnad/subvert.html].

Harnad, S. "The Paper House of Cards (and Why It's Taking So Long to Collapse)." *Ariadne*, 1997, no. 8. [http://wwwariadne.ac.uk/issue8/harnad].

Harter, S. P., and Kim, H. J. "Electronic Journals and Scholarly Communication: A Citation and Reference Study." In *Proceedings of the Midyear Meeting of the American Society for Information Science.* San Diego, Calif., May, 1996 (pp. 299–315). [http://php.indiana.edu/~harter/harter-asis96midyear.html].

Hawkins, J., and Collins, A. (eds.). *Design Experiments: Integrating Technologies into Schools.* New York: Cambridge University Press, forthcoming.

Hitchcock, S., Carr, L., and Hall, W. "A Survey of STM Online Journals 1990–95: The Calm Before the Storm." [http://journals.ecs.soton.ac.uk/survey/survey.html]. 1996.

Hitchcock, S., Carr, L., Hall, W., Harris, S., Probets, S., Evans, D., and Brailsford, D. "Linking Electronic Journals: Lessons from the Open Journal Project." *D-Lib Magazine*, ISSN 1082-9873; December, 1998. [http://www.dlib.org/dlib/december98/12hitchcock.html].

Huberman, M. "Predicting Conceptual Effects in Research Utilization: Looking with Both Eyes." *Knowledge in Society: The International Journal of Knowledge Transfer*, 1989, *2*(3), 6–24.

Johnston, W. E., and Sachs, S. "Distributed Environments (DCEE): Program Overview and Final Report" (draft, version 3). [http://www-itg.lbl.gov/DCEEpage/DCEE_Overview.html]. 1997.

Jordan, B., and Henderson, A. "Interaction Analysis: Foundations and Practice." *Journal of Learning Sciences*, 1993, 2.

Kaestle, C. "The Awful Reputation of Educational Research." *Educational Researcher*, 1993, *22*(1), 23–31.

Kennedy, M. M. "Working Knowledge." *Knowledge: Creation, Diffusion, Utilization*, 1983, *5*, 193–211.

Kennedy, M. M. "The Connection Between Research and Practice." *Educational Researcher*, 1997, *26*(7), 4–12.

Kiesler, S., and Sproull, L. *Connections: New Ways of Working in the Networked Organization*. Cambridge, Mass.: MIT Press, 1991.

Kling, R. (ed.). "The Ethics of Research in Cyberspace." *Information Society*, 1996, *12* (special issue 2).

Kolodner, J. *Case-Based Reasoning*. San Mateo, Calif.: Morgan Kaufmann, 1993.

Kolodner, J., and others. "Roles of a Case Library as a Collaborative Tool for Fostering Argumentation." In R. Hall, N. Miyake, and N. Enyedy (eds), *Proceedings of 1997 Computer Support for Collaborative Learning (CSCL97)* (pp. 150–156). Hillsdale, N.J.: Erlbaum, 1997.

Koselka, R. "Computers/Communications: The Hobby That Is Changing the Business World." *Forbes Magazine*, Oct. 6, 1997.

Kouzes, R. T., Meyers, J. D., and Wulf, W. A. "Collaboratories—Doing Science on the Internet." *IEEE Computer*, 1996, *29*(8), 40–46.

Krajcik, J., and others. "The Casebook of Project Practices—An Example of an Interactive Multimedia System for Professional Development." *Journal of Computers in Mathematics and Science Teaching*, 1996, *15*(1/2), 119–135.

Lanham, R. A. *The Electronic Word: Democracy, Technology, and the Arts*. Chicago: University of Chicago Press, 1993.

Latour, B., and Woolgar, S. *Laboratory Life: The Construction of Scientific Facts*. Princeton, N.J.: Princeton University Press, 1986.

Lynch, M., and Woolgar, S. (eds.). *Representation in Scientific Practice*. Cambridge, Mass.: MIT Press, 1990.

McLaughlin, M. "Lessons from Experience." *Educational Researcher*, 1987, *9*(2), 171–178.

MacKay, W. E. "Ethics, Lies, and Videotape." In *CHI'95 proceedings: Human Factors in Computing System* (pp. 138–145). New York: Association for Computing Machinery, 1995.

Mason, R. D. (ed.). *Computer Conferencing: The Last Word*. Vancouver, B.C.: Beach Holme, 1992.

Mills, M. I., and Pea, R. D. "Mind and Media in Dialog: Issues in Multimedia Composition." In K. Hooper and S. Ambron (eds.), *Full-Spectrum Learning*. Cupertino, Calif.: Apple Computer, 1989.

Mogge, D. (ed.). *Directory of Electronic Journals, Newsletters and Academic Discussion Lists* (pp. 7–32). (6th ed.) Washington, D.C.: Association of Research Libraries, 1996. [http://journals.ecs.soton.ac.uk/survey/survey.html].

Moll, L., and Diaz, S. "Change as the Goal of Educational Research." *Anthropology and Education Quarterly*, 1987, *18*(4), 300–311.

Nathan, M. J., and others. "Promises, Pitfalls, and Recommendations: Multimedia Journal Articles." *Educational Media International*, 1994, *31*, 265–273.

National Center for Education Statistics (NCES). *Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, Fall 1996.* Washington, D.C.: U.S. Department of Education, National Center for Education Statistics, 1997. [www.nces.ed.gov/NCES/pubs].

National Center for Education Statistics (NCES). *Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, Fall 1997.* Washington, D.C.: U.S. Department of Education, 1998. [www.nces.ed.gov/pubsearch/index.html].

National Council for Accreditation of Teacher Education (NCATE). "Technology and the New Professional Teacher: Preparing for the 21st Century Classroom." [ww.ncate.org/specfoc]. 1997.

National Research Council. *National Collaboratories: Applying Information Technology for Scientific Research.* Washington, D.C.: National Academy Press, 1993.

Nelson, T. "The Heart of Connection: Hypermedia Unified by Transclusion." *Communications of the ACM*, 1995, *38*(8), 32.

Newman, D., Bernstein, S., and Reese, P. A. *Local Infrastructures for School Networks: Current Models and Prospects.* BBN Report No. 7726. Cambridge, Mass.: BBN, 1992.

Office of Technology Assessment. *Teachers and Technology: Making the Connection.* Washington, D.C.: U.S. Government Printing Office, 1995. [www.wws.princeton.edu/~ota].

Okerson, A., and O'Donnell, J. (eds.). *Scholarly Journals at the Crossroads: A Subversive Proposal for Electronic Publishing.* Washington, D.C.: Association of Research Libraries, 1995.

Organization for Economic Cooperation and Development. *Education at a Glance: OECD Indicators*. Centre for Educational Research and Innovation. Paris, France: Organization for Economic Cooperation and Development, 1995.

Pea, R. D. "Distributed Intelligence and the Growth of Virtual Learning Communities over the Global Internet." Keynote address for symposium, Distributed Intelligence and Learners' Community: A New Direction for Computer Usage in Education. CIEC Annual Conference, Doushisha University Tanabe Campus, Kyoto, Japan, Aug. 4, 1997.

Pea, R. D. "Augmenting the Discourse of Learning with Computer-Based Learning Environments." In E. de Corte, M. Linn, and L. Verschaffel (eds.), *Computer-Based Learning Environments and Problem-Solving.* NATO Series, subseries F: Computer and System Sciences (pp. 313–343). New York: Springer-Verlag, 1992.

Pea, R. D., and others. "Science Education as a Driver of Cyberspace Technology Development." In K. C. Cohen (ed.), *Internet Links for Science Education* (pp. 189–220). New York: Plenum Press, 1997.

Peek, R. P., and Newby, G. B. (eds.). *Scholarly Publishing: The Electronic Frontier.* Cambridge, Mass.: MIT Press, 1996.

Peters, M., and Lankshear, C. (1996). "Critical Literacy and Digital Texts." *Educational Theory*, 1996, *46*(1), 51–70.

Phelps, T. A., and Wilensky, R. "Multivalent Annotations." In *Proceedings of the First European Conference on Research and Advanced Technology for Digital Libraries*, Pisa, Italy, Sept. 1–2, 1997.

Pool, R. "Beyond Database and E-Mail." *Science*, Aug. 13, 1993, pp. 841–843.

Röscheisen, M., Mogensen, C., and Winograd, T. *Shared Web Annotations as a Platform for Third-Party Value-Added Information Providers: Architecture, Protocols, and Usage Examples.* Technical Report STAN-CS-TR-97-1582, Stanford Integrated Digital Library Project, Computer Science Department, Stanford University, Nov. 1994 (updated Apr. 1995). [http://www-diglib.stanford.edu/diglib/pub/reports/commentator.html].

Roschelle, J., Pea, R. D., and Trigg, R. *VideoNoter: A Tool for Exploratory Video Analysis: Institute for Research on Learning*, Technical Report No. 17. Palo Alto, Calif.: Institute for Research on Learning, 1990.

Roschelle, J., and Zaritsky, R. "Video in Educational Research: A Starter Kit for Investigators of Learning." [http://www.covis.edu/ndec/ProjectPages/Raul_Video/VideoEdResearch.html]. 1995.

Ruopp, R., Gal, S., Drayton, B., and Pfister, M. *LabNet: Toward a Community of Practice.* Hillsdale, N.J.: Erlbaum, 1993.

Salomon, G. "Studying Novel Learning Environments as Patterns of Change." In S. Vosniadou and others (eds.), *International Perspectives on the Design of Technology-Supported Learning Environments* (pp. 363–378). Hillsdale, N.J.: Erlbaum, 1995.

Schatz, B. "Building an Electronic Community System." *Journal of Management Information Systems*, Winter 1991, *8*(3), 87–107.

Schatz, B. *National Collaboratories: Applying Information Technology for Scientific Research.* National Research Council. Washington, D.C.: National Academy Press, 1993.

Schatz, B. R., and others. "Federating Diverse Collections of Scientific Literature." *IEEE Computer*, 1996, *29*(5), 28–36.

Schlager, M. S., Schank, P. K., and Godard, R. "TAPPED IN: A New On-Line Teacher Community Concept for the Next Generation of Internet Technology." In *Proceedings of CSCL '97, The Second International Conference on Computer Support for Collaborative Learning*, Toronto, Canada, Dec. 1997.

Shabo, A., Nagel, K., Guzdial, M., and Kolodner, J. "JavaCAP: A Collaborative Case Authoring Program on the WWW." In R. Hall, N. Miyake, and N. Enyedy (eds.), *Proceedings of 1997 Computer Support for Collaborative Learning (CSCL97)*. Hillsdale, N.J.: Erlbaum, 1997.

SIGCHI. Special Issue on Video Use in Social Science Research. *Proceedings of ACM/SIGCHI Workshop on Video as a Research and Design Tool,* April. Cambridge, Mass.: MIT Press, 1989.

Snyder, I. *Hypertext: The Electronic Labyrinth.* New York: New York University Press, 1997.

Strangelove, M., and Kovacs, D. *Directory of Electronic Journals, Newsletters, and Academic Discussion Lists.* (2nd ed.) Washington, D.C.: Association of Research Libraries, Office of Scientific and Academic Publishing, 1992. [ftp://princeton.edu/pub/harnad/Harnad/harnad91.postgutenberg].

Sumner, T., and Shum, S. B. "Open Peer Review and Argumentation: Loosening the Paper Chains on Journals." *Ariadne* [magazine of the UK Electronic Libraries Programme], Sept. 1996, *5*, 1 [http://www.ukoln.ac.uk/ariadne/issue5/jime/].

Suppes, P. (ed.). *Impact of Research on Education: Some Case Studies.* Englewood Cliffs, N.J.: Prentice-Hall, 1978.

Taubes, G. "Special News Report: Science Journals Go Wired." *Science,* Feb. 9, 1996, p. 764. [Also available in *Science Magazine On-Line* at http://science-mag.aaas.org/science/scripts/display/full/271/5250/764.]

Thomas, J. "Introduction: A Debate About the Ethics of Fair Practices for Collecting Social Science Data in Cyberspace." *Information Society,* 1996, *12*(2), 107–117.

Woodward, H., and McKnight, C. "Electronic Journals: Issues of Access and Bibliographical Control." *Serials Review,* Summer 1995, pp. 71–78.

Wulf, W. A. "A National Collaboratory—A White Paper." In *Towards a National Collaboratory.* Unpublished report of a workshop held at Rockefeller University, Mar. 1989, pp. 17–18.

Zehr, M. A. "Teaching the Teachers." *Education Week,* Nov. 10, 1997, pp. 24–28.

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