August 1999

SRI Project 10099

New Workplace Learning Technologies:

Activities and Exemplars

Bill Penuel, Ph.D.
Center for Technology in Learning
SRI International

Eilif Trondsen
Kermit Patton
Business Intelligence Program
SRI Consulting

Second in a Paper Series:
DESIGNING LEARNING: PRINCIPLES AND TECHNOLOGIES

Primary series author:
Bill Penuel, Ph.D.
SRI international

Series Editor
Andrew L. Cohen, Ph.D.
Lotus Research
alcohen@lotus.com

This paper series was conceived and edited by Andrew L. Cohen of Lotus Research, who envisioned a series of papers aimed at outlining research related to the design of technology-supported workplace learning environments based on the principles of cognitive science. SRI International is responsible for the contents of the papers.

Any questions about these papers should be directed to Lotus Research at alcohen@lotus.com.

EXECUTIVE SUMMARY

Workplace training programs are now beginning to see the power and usefulness of technology to make company learning ubiquitous and cost-effective. For workers to benefit from them, these new technologies must be designed to support work practices of a company. These practices and activities in turn must be designed in accordance with the principles of the cognitive science of learning as discussed in our first paper.

In this paper, we present some ways that innovative companies have used technology to support more effective and powerful learning for workers and their organizations. We have organized the paper around the kinds of technology-based activities that illustrate one or more of the cognitive science principles described in the first paper. In each section, we present examples of effective uses of technology within one or more companies and describe the specific role technology plays in supporting learning there. The end goal for workplace learning is competent *practice*, carried out by a well-coordinated group of active worker-learners, and technologies can be used to support the development of communities of practice organized to enhance learning.

In the paper, we examine how technology has supported the following learning activities within organizations:

Building competence in communities of practice. New collaborative technologies for learning aim to provide an environment wherein novices can come to develop as competent members of a community of practice, in both formal and informal ways. In this section, we present examples of a consortium that used videoconferencing technologies to help community health workers collaborate more effectively and learn key skills in social and environmental health. We also examine the case of Bulab at Buckman Laboratories, an on-line learning environment designed to build a community of practice among scientists and other staff who are distributed across the world.

Developing expertise through problem-based learning. One alternative to traditional corporate learning programs is problem- or scenario-based learning. In problem-based learning, trainers work with experts in a particular community of practice to identify some key problems that workers will need to solve. They identify some successful and some not-so-successful approaches to solving those problems, and then design problems for learners to solve in a training environment that will allow them to gain experience with and expertise in their target work practice. In this section, we present an example from medical training, where problem-based learning has been used widely for 20 years. The IMMEX system is a Web-based problem-solving environment that has been used successfully to distinguish between expert and novice problem-solving strategies in medical diagnosis.

Bridging prior knowledge and learning in novel situations. Simulations, models, and virtual reality provide environments for workers to experience these contextual dimensions of problem-solving in much greater detail. They also allow for workers to practice solving problems in "real time" as contexts change and as new information arises in the course of activity. Third, simulations provide a rich network of systems in context for users to employ to help bridge new understandings with their prior understandings of a domain. In this section, we examine how Andersen Consulting used simulations designed by the Institute for the Learning Sciences to teach its new consultants how to conduct a requirements analysis. Andersen has used the authoring tool used by ILS to create several simulation-based training programs to save money by avoiding bringing learners to a central location.

Structuring participation in collaborative environments. Few technologies are designed specifically to support learners' collaborative reflection on their ongoing work activity. At the same time, much more emphasis is placed on such reflection in schools and, not surprisingly, powerful technologies have been developed to support collaborative reflection focused on student inquiry and research that are themselves powerful aids to learning. In this section, we examine how the CSILE database has been used as a powerful aid to support collaborative reflection about ideas, models, and other visual data such as graphs in an environment that allows learners to display their knowledge of a domain.

In our concluding section, we review two kinds of technologies that support more than one of the different learning activities and that point to ways that a community of practice *designed for learning* can be built over time. These two technologies—MOOs or MUVEs (multi-user virtual environments), and knowledge networking environments—provide opportunities for both formal and informal learning, and while they are not complete learning solutions, they point toward an exciting future direction of workplace technologies for learning.

Introduction: From Principles to Technologies-In-Use

Workplace training programs are now beginning to see the power and usefulness of technology to make company learning ubiquitous and cost-effective. In recent years, training departments in companies have begun using technology to help them handle the challenges of training workers to adapt to work in ever-changing business environments. Still, in 1998 over 83% of corporate training departments in the United States report using traditional classroom methods as the bread-and-butter of their training programs.[1] Training enhanced by learning technologies accounted for only 6% of all training time.[2] They are, moreover, used primarily by larger companies with big training budgets.[3] Companies of all sizes, but particularly smaller ones, cite cost factors and knowledge of available and effective learning technologies as the biggest barriers.[4] Based on these data, one important way to expand the market for learning technologies is to provide companies with effective ways to evaluate the potential of new learning technologies based on what we know about how people learn at work.

In our first paper,[5] we outlined several cognitive science principles for designing workplace learning environments. Learning, we argued, takes place in the course of people's participation in ongoing work activities, within communities of people who do and make things together. Furthermore, the most effective learning takes place when workers have opportunities to solve a variety of problems similar to the kinds of problems they will face on the job. But just solving problems isn't enough: Workers need to be able to apply their problem solving practice "in training" to problem solving practice at work. This frequently involves helping workers to re-organize their prior knowledge and experience so that it becomes useful to them in their current jobs. The opportunity to reflect collaboratively about these kinds of problems and work

---

[1] Bassi, L.J., & Van Buren, M.E. (1998). *1998 State of the Industry Report.* Alexandria, VA: American Society for Training and Development.

[2] Ibid.

[3] Ibid.

[4] Ekos Research Associates, Inc., & L. Green & Associates. (1999). *The impact of technologies on learning in the workplace.* Hull, Canada: Office of Learning Technologies

[5] Penuel, B., & Roschelle, J. (1999). *Designing learning: Cognitive Science Principles for Innovation.* A.L. Cohen (Ed.). First in a paper series for Lotus Research. Menlo Park, CA: SRI International.

practices further enhances both the workers' learning and the organization's repertoire of expertise.

In this paper, we present some ways that innovative companies have used technology to support more effective and powerful learning for workers and their organizations. We have organized the paper around the kinds of technology-based activities that illustrate one or more of the cognitive science principles described in the first paper (see Table 1). In each section, we present examples of effective uses of technology within one or more companies and describe the specific role technology plays in supporting learning there. Our review does not provide an exhaustive list of design features that a company could use as a checklist to determine whether the technologies they use maximize the learning possibilities for their workers. Instead, we focus on learning activities as they take place in particular workplace settings, examining how the technologies fit into and transform ongoing work practice.

Table 1.

Learning Activities to Support Cognitive Principles of Learning

Technology-Supported Learning Activities	Cognitive Principle
Building competence in communities of practice	Learning takes place within communities of practice.
Developing expertise through problem-based learning	Novices learn to become experts through practice in solving a variety of problems in a domain.
Bridging prior knowledge and learning in novel situations	Becoming an expert means applying learning to new contexts. Prior knowledge mediates learning.
Structuring participation in collaborative environments	Learning is enhanced when thinking is made visible by collaboration and reflection among learners.

Why Focus on Activities?

There is a tendency to speak of new technologies in terms of what they can *do* for us. We have terms like "agents," moreover, that suggest the idea that our technologies indeed can *act*—granted with a little programming and assistance from people—in ways that are liberating and transforming. But speaking this way about technology hides the ways that people, tools, and situations are all connected by particular activities. It is this larger unit—activity—that is critical to examine if we want to investigate the impact of technology on workplace learning. It's indeed possible that new technologies may transform activity, but they do so only to the extent that people, processes, and contexts also change and are changed by new technology.

We focus then on *activities* as contexts for technology-supported learning because the goals, people, institutions, and technologies all come together in the particular way that communities of practice do what they do together. It is not possible to identify a menu of technologies that have particular design features and capabilities that a company can employ to maximize learning. The power of a particular tool lies not in the technology in itself but in what people can accomplish when they use technology to learn while accomplishing significant tasks or solving important problems at work. The end goal for workplace learning is competent *practice*, carried out by a well-coordinated group of active worker-learners, and technologies can support the development of communities of practice organized to enhance learning.

Building Competence in Communities of Practice

How do groups of people who work together develop shared ways of interpreting the stories that in turn shape how they do their work? To answer this question, we would probably want to follow a new hire fresh out of college or business school for a while and observe as this novice engages with different people on the job. If this new hire is lucky, some of what she learns may come from an initial off-site training week, where the eager new hire learns what is expected of her in her new job and how to perform routinized tasks of her job. However, much of what is learned comes through the course of interacting with co-workers on projects. The novice learns how to do her job by contributing to the work, listening and watching for the reactions of others, and adjusting her actions accordingly throughout the day on a myriad of projects. Over time, the novice begins to recognize patterns of work, patterns in how people respond to her, and patterns in how she regulates her own thinking and work. The richness of face-to-face engagement with others is an important resource for learning.

New collaborative technologies for learning aim to provide an environment wherein novices can come to develop as competent members of a community of practice, both formally and informally. These technologies have a difficult task—to provide support for workers to develop competence when they are in many cases separated in space and time from other learners. To be sure, designers of collaborative technologies have a rich history of efforts in distributed learning to draw upon.

In the past, it has been possible for companies to create a common community of practice by taking advantage of the proximity of workers to one another. People working in the same location could all attend training sessions together, take advantage of opportunistic encounters in the hallway to share company news, or schedule meetings with each other to plan their activities. These social encounters build up a common history of mutual activity and engagement, a prime ingredient in the construction of communities of practice.[6]

Increasingly, companies are looking for learning solutions that allow workers to acquire critical enterprise knowledge and skill when employees are geographically dispersed and cannot meet at the same time and place for training. The challenge for companies is not just to ensure that workers transfer a discrete set of skills but also to make sure workers learn the feel and culture of the company. Workers still need some way to interact with others to check their developing understanding of what it is they're supposed to do on the job. Solving the problems of distributed learning, then, involves defining new ways to develop communities of practice supported by collaborative technologies.

Education at a distance is not a new form of learning. Correspondence courses offered through major American universities were established in the late 1800s.[7] At the time, these courses were seen as inferior to classroom instruction, a kind of second-hand education that could hardly confer the kind of rigorous knowledge that attendance at a university or campus

[6] Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

[7] McIsaac, M. S., & Gunawardena, C. N. (1996). Distance education. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 403–437). New York: Macmillan.

would confer.[8] In recent years, distance education has grown beyond colleges and universities to include public and private organizations, the military, and large corporations. It is seen as a necessity at a time when the costs of bringing employees to a central training site and providing them with food and lodging is becoming more and more expensive. Distance education, or *distributed learning* as it is now often called, provides opportunities for workers in companies to learn just about anywhere they happen to be—at their desk, on the road, or at home.

Technologies to support learning at a distance have themselves transformed rapidly in the past two decades. In the late 1970s and early 1980s, an array of individual tools emerged to support learning at a distance. Bulletin-board systems were first developed in the late 1970s, which allowed users to post and read information on a network. Computer conferencing systems were first used for course activity and delivery in the early 1980s. Conferencing systems were the first technologies to allow for completely "on-line" or "virtual" learning, in that they provide users with software embedded in virtual "spaces" in which they can navigate, review material, and make contributions. Among other things, videoconferencing has allowed a shift from individualized, self-directed learning to collaborative learning.[9] Among the first educational uses of conferencing were non-credit mini-courses, executive training programs, and college-level courses.[10] Interestingly, while many of these new technologies were designed to support higher education purposes, business practices have become more and more important as contexts for the development of new learning technologies.

In some cases, videoconferencing has shown promise in supporting learner collaboration and acquisition of knowledge. An early user of videoconferencing, the Danish consortium involving the Jutland Institute of Technology and Aarhus Technical College in Denmark is illustrative. The consortium used the COM conferencing system, at its time a sophisticated conferencing tool, to support on-the-job training for community health workers.

---

[8] Pittman, V. (1991). Rivalry for respectability: collegiate and proprietary correspondence programs. *Second American symposium on research in distance education.* University Park, PA: Pennsylvania State University.

[9] Lauzon, A.C., & Moore, M. (1989). Enhancing accessibility to meaningful learning opportunities: A pilot program in online education at the University of Guelph. *Research in Distance Education, 3*, 2–5.

[10] Harasim, L., Hiltz, S. R., Teles, L., & Turoff, M. (1995). *Learning networks: A field guide to teaching and learning online.* Cambridge, MA: MIT Press.

All users had access to this system, whether at home or at their desktop at work. Students defined themes and topics for the courses and formulated problems to investigate. Each team of students spent over two months completing projects, which were designed to become a part of workers' ongoing practice. Experts provided up-to-date subject-matter knowledge in the areas of social and environmental health. At the end of the project, groups met face-to-face to present their projects. Students indicated that the course was valuable and reported gains in knowledge they felt would be useful to them on the job. The students said that learning on-line made it easier for them to collaborate: share drafts, comment on ideas, and make use of people's special gifts.[11]

In other instances, videoconferencing has been less than successful in supporting workplace learning. Harasim, Hiltz, Teles, and Turoff[12] report results from a hospital management organization's corporate training program. The management had requested that three professional development courses be offered on-line to a small group of employees. Management selected the topics for the courses and nominated all participants. To build a sense of community, the courses began with an on-site training session. Each course had four modules, and short "e-lectures" were delivered each week to students, as were questions for discussion. Moderators made requests that participants bring in job-related situations for discussion. Many participants, though, never signed on, and those who did didn't write much. There was too little motivation to participate or time to participate. Management had not reduced these workers' load, and there was no immediate payoff for participation. Moreover, access was a problem. Workers could not access the system via notebook computers, and in many cases, workers did not have access at their desks.

These two examples, both from the same industry, illustrate the central importance that the larger social and organizational context plays in shaping the success of learning technology. In the Danish consortium, learners were self-directed, defining areas of investigation based on their interest. Experts provided relevant and important content, but only as requested by

[11] Ibid.
Hiltz, S. R., Shapiro, H., & Ringsted, M. (1990). Collaborative teaching in the virtual classroom. *Proceedings of the Third Symposium on Computer Mediated Communications* (pp. 37-55). Guelph, Ontario: University of Guelph.

[12] Harasim, Hiltz, Teles, & Turoff. (1995).

workers. In the second company, by contrast, management defined the content and mandated attendance in the training courses. At the same time, they provided no incentives for participation, which sent a mixed message to workers. The training, workers interpreted, was important to management, but the incentives the company had previously set up to reward ongoing work were still the ones by which workers would be judged. Workers got the picture, and they responded accordingly. As a result, there was little participation in the courses, and little peer learning occurred.

In recent years, courseware or "learnware" as it has sometimes been called has been developed to support more complex learning needs of organizations. These systems are designed to provide "anytime, anyplace" learning for workers, and are often designed to help focus strategic learning in companies, solve real business problems and provide learning on demand using a learning-by-doing approach.[13]

Buckman Laboratories, a chemical company based in Memphis, Tennessee, has been investing heavily in on-line corporate learning for over a decade. Under the leadership of its CEO, Bob Buckman, Buckman Labs has created the K'Netix knowledge network and Bulab University, an on-line learning environment to support staff development at the company. Buckman created these on-line learning environments because the company needed a learning solution to fit the needs of its workers: At any given time, the company figured that 86% of its staff is out of the office—making sales calls, conducting research, or providing consulting services.[14] Bulab University includes a variety of software tools within its architecture. In the past, it has used CompuServe as an access tool for electronic conferencing. To measure workers' skills and proficiencies and aid with career planning, Bulab uses a tool called Ingenium, from Asymmetrix. Bulab also employs LearningSpace, which allows companies to create, catalog, schedule, and manage courses, register students for courses and automate the process, create learner profiles, and track usage of the system. The technology supports asynchronous discussions and e-mail among students and between learners and experts, as well

---

[13] Meister, J.C. (1998). *Corporate universities: Lessons in building a world-class work force*. New York: McGraw-Hill.

[14] Rumizen, M. (1998). How Buckman Laboratories' shared knowledge sparked a chain reaction. *The Journal for Quality and Participation, 3*, 34–38.

as collaborative document construction. Bulab uses LearningSpace to support broad training curricula, such as training in specific work practices, leadership and workplace social skills, technology skills, and even the history and culture of a company. Currently, nine staffers develop courses in four different languages, and many courses blend on-line and classroom approaches, depending on the content.[15]

The success of Buckman Laboratories' learning environments lies not simply in the array of tools available to workers but in how the company has used technology to support distributed *informal* workplace learning. The company has developed a Web site using Lotus/Domino technology where associates are creating networks of support within and across different communities of practice (e.g., chemists and consultants) in the company. Associates can access contacts, expertise, and resources on knowledge management through the company's Knowledge Nurture Web site (www.knowledge-nurture.com). Threaded discussions allow for asynchronous discussions about knowledge management at the company. Net Meeting capabilities mean associates can also engage in real-time discussion. Interestingly, Buckman has made many parts of this Web site accessible to workers outside the company, in part to enable knowledge to flow freely across company boundaries.[16]

Buckman's efforts have been widely recognized in the field for the way their technology-supported learning environments enhance knowledge sharing within the company. The company has won an Arthur Andersen Enterprise Award, a Computerworld Smithsonian Award for innovative applications of technology, and a Delphi Group award for establishing successful learning communities. The company has been recognized not just for creating such systems as K'Netix and Bulab but also for the impact these learning environments have had on the company's bottom line. In the years since K'Netix was first established at Buckman, the company has shortened the time it takes to get an innovative product to market: the average sales of products less than five years old had gone up by 50%.[17]

---

[15] Wheeler, K. B. (1999). Bulab University strives to build career fitness. *Corporate University News, 2,* 3–4.

[16] Ibid.

[17] Arthur Andersen. (1996). 996 Enterprise Award Honoree: Sharing Knowledge in the Organization. [on-line]. Available: http://www.knowledge-nurture.com.

Developing Expertise Through Problem-Based Learning

A key problem faced by designers of workplace learning environments is to create contexts wherein learners can encounter the kinds of problems they face on the job. This is no easy task, since most of the people who design corporate learning programs have expertise in training and organizational development, but not in the kinds of practices that those whom they are training will need to master. As a result, many corporate training programs produce documents and training guides that are far removed from the day-to-day problems faced by workers on the job.[18]

An alternative to training manuals and traditional curricula can be found in problem- or scenario-based learning. In problem-based learning, trainers work with experts in a particular community of practice to identify some key problems that workers will need to solve. They identify some successful and some not-so-successful approaches to solving those problems, and then design problems for learners to solve in a training environment that will allow them to gain experience with and expertise in their target work practice.

Problem-based learning has been used for many years in higher education, most often in the teaching of medicine.[19] Recently, two reviews have summarized more than 20 years of evaluations of problem- or case-based learning in medical education.[20] These studies show that medical students who participate in problem-based learning programs perform as well as students in traditional programs on conventional tests of medical knowledge. In addition, these medical students do better on tests of clinical problem-solving skills than those students who are schooled in more traditional methods.

---

[18] Schank, R. (1997). *Virtual learning: A revolutionary approach to building a highly skilled workforce.* New York: McGraw-Hill.

[19] Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. In L. Wilkerson & W. H. Gijselaers (Eds.) *Bringing problem-based learning to higher education: Theory and practice* (pp. 3–12). San Francisco: Jossey-Bass.
Williams, S. M. (1992). Putting case-based instruction into context: Examples from legal and medical education. *The Journal of the Learning Sciences, 2*, 367–427.

[20] Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*, 52–81.
Vernon, D. T. A., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluation research. *Academic Medicine, 68*, 550–563.

Today, there are technology supports for the assessment of student learning in problem-based learning environments. For example, in the Interactive Multi Media Exercises (IMMEX) program developed by Dr. Ron Stevens of the UCLA School of Medicine's Immunology Department, learners solve problems they are likely to encounter in the context of their work practice. The program uses neural network analysis to characterize different kinds of problem-solving strategies.[21] In one problem in the IMMEX system, for example, medical students are asked to prescribe a course of treatment for a young student who comes to a community health center with symptoms of asthma. The students are given a range of documents, some of which are more or less useful than others in solving the problem. Some of the documents include testimony from the patient's family about symptoms, while other documents provide medical students with an opportunity to consult a specialist. Each information source consulted "costs" the student money, just as a real consultation would cost a physician. The goal is to support medical students' learning to make an accurate diagnosis using the fewest points (minimizing costs) and most efficiently (using expert search patterns).

Initial studies of student problem solving using the IMMEX system indicate that the neural network analysis that is performed on student search strategies can effectively distinguish novice and expert strategies used to solve these medical diagnostic problems.[22] Importantly, as in actual medical problem-solving, the system allows learners to search on their own without cutting off investigation: The only limitations are the number of points used and the user's interests or frustration levels. The analysis showed that novice students' search patterns were broad and not guided by knowledge or theory in medical diagnosis. As student understanding of the domain increased—both by traditional independent "textbook" learning and by exposure to problems in the learning environment—the search strategies of students became more refined. A few approximated what the computer itself could create as an expert strategy, defined as the most efficient strategy for gaining the correct solution to the problem. Moreover, follow-up

[21] Stevens, R.H., & Najafi, K. (1993). Artificial neural networks as adjuncts for assessing medical students' problem solving performances on computer-based simulations. *Computers and Biomedical Research, 26,* 172–187.

[22] Stevens, R.H., Lopo, A.C., & Wang, P. (1996). Artificial neural networks can distinguish novice and expert strategies during complex problem solving. *Journal of the American Medical Informatics Association, 3,* 131–138.

studies indicated that most medical students who scored among the lowest 10% of their class on multiple problems in the IMMEX environment were either on leave of absence or had dropped out by their second year of medical school.[23]

IMMEX has some design features that contribute to its being such a powerful learning and assessment tool. IMMEX: Author/Delivery, for example, allows experts in a field to design their own problems and create problem-based learning scenarios within any field that will support the kinds of assessment that Stevens has developed for medical students. The IMMEX: Analysis module provides a range of assessment tools for measuring student problem solving and producing group-level and individual-level representations of learners' search patterns. The Analysis module is the heart of what makes IMMEX an effective tool for providing feedback to designers and learners about the development of expertise. Through statistical analysis, "novice," "becoming expert," and "expert" problem-solving patterns can be identified. Instruction can then be targeted to learners depending upon how their own search patterns are evolving through repeated practice with problems in the target domain.

Of course, the IMMEX system is best suited for helping students learn how to solve problems that allow one or more "correct" solutions to the problem. Ill-structured problems, in which the problem space itself is difficult to define or in which many possible solutions to a problem exist, pose a problem for authors of IMMEX cases. Rich, open-ended representations of problems are needed for these kinds of situations. We turn now to consider some tools that help learners gain such rich representational competence through interacting with simulations, modeling tools, and virtual spaces.

Bridging Prior Knowledge and Learning in Novel Situations

One limitation of many problem based learning tools is that they do not model problem solving in "real time." In other words, the problem space remains the same throughout the activity, and users can take as much or as little time as needed to solve the problem. On the job, however, workers must solve problems that are themselves constantly changing, and when workers begin solving a problem, the problem changes, and other people involved in solving the

[23] Stevens, R., personal communication, May 26, 1999.

problem provide feedback to workers. Moreover, there are usually tight deadlines to solving problems, and workers must develop skill in solving problems quickly and efficiently. The accuracy and speed is often reflected in customers' (and potential customers') attitudes toward the company, since some of the most complex problem solving involves customer interaction.

Simulations, models, and virtual reality provide environments for workers to experience these contextual dimensions of problem-solving in much greater detail. Simulations provide a rich network of systems in context for users to employ to help bridge new understandings with their prior understandings of a domain. When everyday knowledge needs to be re-organized so that people learn to see a problem differently (i.e., through the lens of the target workplace practice), good simulations can be powerful aids, because they put learners in situations where their habitual modes of perceiving, feeling, and responding to events are activated. When these habitual modes of responding do not support desired problem-solving practice, simulations often provide immediate feedback in the moment to users about the possible consequences of their decisions. They thus allow the learner to self-correct and try new approaches until they succeed in mastering the new problem-solving practice.

Some simulation and modeling software also allows trainers and other experts to author their own scenarios. These tools have the added benefit of preventing expertise and competence from being "frozen" in time while the wider business and learning contexts are still changing.[24] We will examine the implications of using these kinds of software in greater detail in the third paper, when we present illustrations of how designing and creating models and simulations can be used as a workplace learning tool.

Engaging workers with computer simulations and modeling can be a more powerful way to support workplace learning. Good simulations encourage workers to learn by taking risks and making mistakes, and they provide workers with an occasion for reflection about their practice.[25] We present a successful example of how simulations have been used to support workplace learning by involving learners in solving problems of the kind they might face on the

[24] For a review of the dangers of "freezing" representations of consciousness, see Star, S. L. (1995). The politics of formal representations: Wizards, gurus, and organizational complexity. In S. L. Star (Ed.), *Ecologies of knowledge: Work and politics in science and technology* (pp. 88-118). Albany, NY: SUNY Press.

[25] Schank. (1997).

job. Our example is taken from a company whose function is to help other companies enhance workplace processes: Andersen Consulting.

Andersen Consulting invests over $200 million per year in training its international team of consultants. As part of their introductory training, new staff members were traditionally brought to the company's St. Charles, Illinois, training facility. Flying employees to the training site— in some cases several thousand miles—and housing them for several days is a significant proportion of the total training cost. Some years ago, Andersen asked the Institute for Learning Sciences (ILS) at Northwestern University to design a set of simulations that they could run on a computer desktop to help train new staff in key business-consulting practices.

One set of simulation software that ILS designed for Andersen was intended to teach new hires how to conduct a requirements analysis. Requirements analysis includes a thick description of what a newly re-engineered system is to accomplish and an analysis of the current system. It is a core component of Andersen's consulting practice: Without a diagnosis of how existing workplace processes contribute to making the company's products or delivering its services, Andersen's consultants cannot expect to make recommendations for improving workflow that can be implemented and that will have the desired effects. At the same time, it is easy for novices to miss important dimensions of a company's processes and thus generate a faulty solution for the company, which, if such recommendations were made often, would put Andersen quickly out of business.

ILS designed three different modules to help novices to Andersen learn how to conduct a requirements analysis.[26] Workers complete the first two modules individually, and the third module by working in teams in front of a single computer. The first module presents learners with an admittedly fictional simulation, designed to convey the significance of requirements analysis. Learners must construct requirements for a restaurant for "Zed," an alien who knows nothing about restaurants but who wants to build one here on Earth. At the beginning of this module, learners are presented with an initial video of a scene in a restaurant, which begins with a hostess seating a customer and concludes at the end of the meal, when the bill is paid and the customer's change is returned. This scene is intended to function as a reference point for the

[26] More detailed descriptions of these modules can be found in Schank (1997).

learners, one that shows a smoothly functioning restaurant. Next, users put in their own requirements for Zed's restaurant. Novices inevitably leave out things (such as getting people menus). They are then shown a video of Zed's Restaurant as it would operate given their requirements. If something is missing, it is typically obvious to the learner, because an expectation they have about how restaurants function is violated. For example, if getting menus to customers were left out, then the customer would not be able to order any food. When they make mistakes, learners are given the chance to revise their requirements analysis and re-run the video of Zed's Restaurant until the restaurant is working smoothly.

The second and third modules are more focused on the kinds of problems Andersen's consultants are likely to see in the field. Users work in teams and are presented with problems as the company sees it and must conduct a requirements analysis to solve the problem. In the second module, some of the work is done already for the learners. They have access to "war stories" from other Andersen consultants that pop up when learners make a risky decision. These war stories come from actual client engagements and are designed to help learners steer toward a more effective solution to the problem. They also have access to a virtual supervisor, who provides periodic feedback on their performance. In the third module, no work has been done for them on the requirements analysis, and the coach is increasingly demanding of workers' self-reliance. The coach is much more like a real supervisor, expecting the teams to work fairly independently and autonomously without much outside help.

The simulations have proven to be a powerful tool for Andersen. Through the failures that learners inevitably encounter, they become more actively engaged in solving the problems of requirements analysis and buy into the idea that this is an important skill to master.[27] Moreover, the simulations provide one possible tool for reducing overall training costs. Although ILS took some 18 months to design the first set of simulations for Andersen, once a process was in place at the company for designing simulations, the total time was reduced by two-thirds. Finally, as a testament to the simulations' success, Andersen continues to use the authoring tool provided by ILS to design new simulations to teach new skills to its consultants.

[27] Ibid.

Structuring Participation in Collaborative Environments

The technologies we have reviewed thus far have been designed either to provide a basic architecture for collaboration to support learning core work activities. Few technologies are designed specifically to support learners' collaborative reflection on their ongoing work activity. Many companies struggle to find the time to develop tools to support reflection, even though ongoing thinking-in-action and reflection on company activity is a core concept within organizational learning.[28]

Within schools (K-12 and higher education), there is much more emphasis placed on such reflection and, not surprisingly, powerful technologies have been developed to support collaborative reflection focused on student inquiry and research that are themselves powerful aids to learning. Cohen and Scardamalia[29], for example, highlight the unique contributions of technology to support inquiry-based learning in science. They examined the patterns of talk of 30 fifth/sixth grade students from a single classroom in Canada as they used computer simulations to construct experiments to learn about gravity.

Each student conducted experiments in two conditions. In one condition, students worked in groups around a single workstation that ran the simulation Interactive Physics and wrote down their findings using pencil and paper. In the second condition, students not only used the Interactive Physics program but also used the CSILE (Computer-Supported Intentional Learning Environment) database to record their work. In the CSILE condition, students stored and organized the data they collected into a common database. These data can be textual or graphical and may include models or representations students have created to depict what they know. They kept annotated notes about their work that included key words, a title, and a "thinking type" (e.g., "What I already know," or "I need to understand") aimed at helping students regulate their own thinking. In CSILE, all students can access and comment on one another's ideas or use a search engine to look for specific information. The design features

---

[28] Schon, D.A. (1983). *The reflective practitioner: How professionals think in action.* New York: Basic Books.

[29] Cohen, A.L., & Scardamalia, M. (1998). Discourse about ideas: Monitoring and regulation in face-to-face and computer-mediated environments. *Interactive Learning Environments, 6,* 93–113.

of CSILE are intended to support students' focusing their efforts on their own and their peers' ideas about the project at hand, regulating their own and others' thinking, and engaging in deep sense-making in the target domain.

Cohen and Scardamalia[30] found that in the CSILE condition, students engaged in much more monitoring and regulation of each others' ideas than in the face-to-face conditions. They also found that there was much more equitable collaboration in the CSILE condition, and students focused more on the problems at hand in their discussion.

The findings here suggest some specific ways that collaborative technologies like CSILE might support greater learning in schools and in the workplace. First, they transform individual learners' ideas into public artifacts, which can become the focus of conversation, revision, and knowledge-building. Second, these tools can enhance the way in which learners work with each other by making visible to peers the quantity and quality of contributions that individuals make in the course of learning activity. Technologies like CSILE, then, could be developed in the workplace to support the construction of rich knowledge networks wherein workers draw on one another's ideas to construct expertise and where workers can test their ideas on their peers before "going live" with innovation and risky ventures.

Pointing Toward the Future: Technologies That Support Multiple Learning Activities Within a Community of Practice

In each of the examples we have presented above, technology has played an important role in supporting primarily *one* of the learning activities associated with the cognitive science principles we discussed in our first paper. In our concluding section, we review two kinds of technologies that support more than one of the different learning activities and that point to ways that allow a community of practice *designed for learning* to be built over time. These two technologies provide opportunities for both formal and informal learning, and although they are not complete learning solutions, they point toward an exciting future direction of workplace technologies for learning.

[30] Ibid.

Multi-User Virtual Environments for Learning

One technology that supports collaboration and learning through doing are MOOs (which stands for Multi-User Dungeon Object Oriented Environments) or MUVEs (Multi-User Virtual Environments). A MUVE is a networked virtual environment, usually text-based, wherein multiple users can interact in real time while engaging in programmed activities or in activities they themselves are designing. Users typically telnet in order to connect to the MOO, where they log on as members or as guests to the particular MOO. Early MOOs were entirely text-based, but contemporary MOOs and MUVEs often have a graphical interface that represents the virtual place in a form familiar to most users, e.g., a floor plan. MUVEs are built on the premise that both *place* and *activity* are significant determinants of human learning. Being in the same virtual place provides opportunities for creative interaction that may not be anticipated by designers. Users themselves appropriate the environments' tools and design their own to engage in mutual activity, which may be formally planned or opportunistic.

MOOs have historically not been given much attention in business, in part because they have been widely used for primarily recreational activities.[31] At the same time, many industries have begun to explore MOOs as significant media for learning and communication. Towell and Towell[32] cite several organizations that have investigated MOOs for business purposes: the National Institutes of Standards and Technology; a systems administration group at Northeastern University, and conference organizers of the Electronic Computational Chemistry Conference.

Researchers at SRI International have developed TAPPED IN, a teacher professional development MUVE designed to build professional communities of practice for teachers across the United States. The idea for TAPPED IN was to create an on-line environment where

[31] Evard, R. (1994). Collaborative networked communication: MUDS as systems tools. Proceedings of the Seventh Systems Administration Conference (LISA VII). Available http: Hostname: www.ccs.neu.edu; path: /home/remy/documents/cncmast.html
Towell, E. R., Yim, A., & Lam, T. (in press). Utilization of Internet Services and the Teaching of Internet in Business School. *The Journal of Computer Information Systems*.

[32] Towell, J., & Towell, E. (1995). Internet conferencing with networked virtual environments. *Internet Research*, *5*, 15–20.

teachers could learn about school reform concepts, engage in informal collaboration with peers, and find high-quality teaching resources.[33] TAPPED IN has invited school districts, school reform organizations, and organizations with a strong background in teacher professional development to participate in what researchers originally hoped would be a highly-trafficked environment that combines formal and informal learning. These organizations provide much of the backbone to the MUVE's activities, but independent teachers and other education professionals also inhabit TAPPED IN.

The design of the TAPPED IN environment resembles a conference center. There are four floors of virtual meeting rooms, offices, and public areas (arrayed in North, South, East, and West wings) containing familiar discourse-support artifacts such as shared whiteboards and bulletin boards. As in other MOOs, members can name and furnish their own offices, create and share text documents and WebViewers (TAPPED IN objects that hyperlink to specified Web sites), and post items in their workroom. Users can perform most design-related and other actions by clicking on objects in the Web window. Communication is entered and viewed in a text window, but users with access to today's Web browsers can navigate through a visually inviting environment that integrates text and graphics.

To a great extent, TAPPED IN has been successful in supporting both the building of a community of practice among teachers centered about professional development and promoting collaborative reflection on teaching practice. The environment has several thousand members, and a large number of teachers have participated in short on-line courses and formal chats with experts in school reform. Teachers have drawn on resources placed in files and taken advantages of professional development opportunities from notices posted in TAPPED IN. There have been regular informal "chats" in TAPPED IN among individual members, who meet in TAPPED IN to have a real-time discussion or who take advantage of "bumping into" people in virtual space. These discussions have centered about such topics as assessing student learning, developing technology plans, and identifying effective professional development

[33] Schlager, M., & Schank, P. (1997). TAPPED IN: A New On-line Teacher Community Concept for the Next Generation of Internet Technology. In *CSCL '97, The Second International Conference on Computer Support for Collaborative Learning.*

strategies—all central aspects of teaching practice in which teachers are engaging in on-line, real-time collaborative reflection.

To support collaboration focused about actual teaching practice, TAPPED IN also has a Student Activities Center, where teachers may take their students to participate in on-line forums and other activities. One group of high school teachers from California, Pennsylvania, and Indiana has used the Student Activities Center to host a discussion of civil rights with their students.[34] Teachers met on-line for two months to plan for the class, design student activities leading up to the forum, and identify strategies for breakout sessions. One focus of the planning sessions was on student assessment and evaluation. Teachers from the different states learned that each had different criteria for judging student research and assessing the quality of on-line interaction. In the end, the group's facilitator crafted a rubric that represented the joint work of the teachers on-line.

This kind of collaboration within teaching is rare. Teachers are often isolated within their classrooms, especially at the high school level where team teaching is not widely practiced. Discussion about measuring the quality of student work is an emerging and important issue in education, but without venues for discussing assessment issues in the context of real teaching practice, teachers rarely have opportunities to know how to implement innovative assessment practices in their classroom. TAPPED IN provided just such an environment for teacher collaboration and reflection on practice.

Technologies for Knowledge Networking

Knowledge networking involves the use of electronic links across different communities of practice to facilitate knowledge creation and sharing.[35] Knowledge networking is often considered a tool for knowledge management, but it is equally a tool of workplace learning. Learning, as we discussed in our first paper, is after all about workers' constructing knowledge together. Through participation in knowledge networking activities, workers come to learn

[34] Nystrom, H. (1998). TAPPED IN and student civil rights forum. *Converge, 1,* 24–26.

[35] Definition from Harasim, Hiltz, Teles, & Turoff. (1995).

important tacit and implicit knowledge about how companies solve problems and how workers use each other's expertise.

British Petroleum (now BP/Amoco) established a knowledge network aimed at helping workers learn from each other's expertise. BP's Virtual Team Network is aimed at helping the company develop records of know-how within the company to solve problems so workers at remote sites can use them as needed.[36] BP created a Web-based virtual team network aimed at allowing people to work cooperatively and share expertise remotely, alone and across teams and organizations. All users in the network have the capability to develop their own home page. In many cases, Web pages have been created by experts within the company that describe their expertise and experience. Other sites contain technical data and share information on cost-cutting ideas. BP encourages people to list their interests, expertise, and experience. Since the start of the Virtual Team Network, some 40,000 pages of information have been created. Moreover, knowledge developed through the Virtual Team Network has helped reduced the amount of time it takes for the company to develop an oil field and has cut project costs in some cases by 58%.[37] Among other benefits of the network are a large decrease in the cost of solving problems involving engineers and offshore rig crews; avoidance of refinery shutdowns; and a reduction of rework during construction projects because designers, fabricators, construction workers, and operations staff could collaborate more effectively.[38]

BP's Virtual Team Network supports the building of communities of practice centered on providing its users with experiences in solving a broad array of problems that workers face on the job. Users have the opportunity to develop identities as competent members of communities of practice by sharing their expertise company-wide. When their expertise is used, this virtual identity—made public through the company Web pages—is reinforced, and the company has effectively drawn upon its expertise to solve a real problem faced by the company. Through their use of the system, workers come to learn about a much wider array of problems faced by other workers in the company than by learning only from their co-located

[36] Prokesch, S. E. (1997). Unleashing the power of learning: An interview with British Petroleum's John Browne. *Harvard Business Review*, (Sept–Oct) 1–19.

[37] Ibid.

[38] Ibid.

coworkers. Through the sharing of expertise, the Virtual Network provides users not only with exposure to problems but also to solutions.

The Challenge: Designing Integrated Learning Environments for the Workplace

In many companies, virtual and "real" communities of practice and their development are not the focus of learning and training departments. Training courses—whether offered through a university or through corporate training departments—can only occasionally provide the support to develop communities of practice. Most courses are too short to develop a shared history of working together, much less a repertoire for how to solve problems. In many courses where, for instance, workers are learning a new spreadsheet program, they may not share many workplace practices at all. Moreover, when courses are one step removed from workplace practice, the incentives to broaden or deepen one's participation in a course are often missing. Even in successful on-line communities of practices such as Knowledge Nurture at Buckman Labs, the lack of specific incentives for participation is a barrier to learning.[39]

In our third and final paper in this series, we will take up in greater detail how knowledge networks can support robust learning both in formal training and in the context of ongoing practice. Specifically, we consider how different technologies and knowledge management strategies can support learning for two different kinds of learners: novices and experts. We'll also discuss how communities of practice, problem-centered learning, and leaving traces of knowledge throughout the organization contribute to the twin aims of managing knowledge and promoting workplace learning.

[39] Comment by Melissie Rumizen (11/19/98) on in the public Meeting Room at www.knowledge-nurture.com

SRI International performed research and prepared a report as an account of work for Lotus Development Corporation. Neither SRI International, its officers or employees, nor any person acting on behalf of any of them make any representations with respect to the use of the information contained in SRI's report, nor does SRI endorse, expressly or by implication, Lotus' use of any SRI provided information