Symposium: Learning on Demand

Organizers: Michael Eisenberg and Gerhard Fischer
Department of Computer Science and Institute of Cognitive Science
Campus Box 430, University of Colorado, Boulder CO 80309

Participants: John Anderson, Department of Psychology, Carnegie-Mellon University, Pittsburgh, PA 15213
William J. Clancey, IRL, 2550 Hanover St., Palo Alto CA 94304
Wallace Feurzeig, BBN, 10 Moulton St., Cambridge MA 02138
Joan Greenbaum, Computer Information Systems Dept., LaGuardia College (CUNY), 31-10 Thomsen Ave., Long Island City, NY 11101
John Thomas, NYNEX, 500 Westchester Ave, White Plains, NY 10604

Overview

The symposium discussion will focus on the following questions:

1. What patterns of usage of learning-on-demand systems support (or discourage) integration of knowledge? What can we, as system designers, do to facilitate the "beneficial" patterns of usage?
2. What kinds of expertise are in fact attained by users of these systems: do they learn terminology, internalize a collection of favorite (or illustrative) examples, assimilate a sense of "taste," develop meta-knowledge about making good use of the systems themselves?
3. What is the role of motivation in learning-on-demand systems? Are users motivated purely "locally," wishing to finish some particular job; or do they experience a more "global" motivation in learning domain knowledge or learning about the system?
4. Can learning-on-demand systems support creative work? Do users of these systems eventually outgrow the particular examples or critiquing rules supplied with the system? Do they develop a personalized vocabulary or an individual style of work?

The participants of the symposium have been involved with different aspects of learning on demand for several years (e.g., design and use of intelligent tutors, situated cognition and learning, intelligent tools, work-oriented design of artifacts, learning-on-the-job, programmable design environments, critiquing systems, and human-centered intelligent agents). These different background perspectives will be brought together to assess the state of the art and the future promises and challenges for learning on demand.

Michael Eisenberg and Gerhard Fischer: Learning on Demand — Why Is It Necessary and Why Does It Make a Difference?

Two fundamental problems have accompanied the increasing prevalence of complex, high-functionality software applications: (1) the impossibility of *coverage* for these systems (i.e., it is impossible to teach users everything that they might need to know about the system in the future), and (2) the inevitability of *obsolescence* (the system cannot be designed to include everything that a user might conceivably require). The result is a need for systems in which functionality may be encountered, learned, practiced, and extended in the course of ongoing use—in other words, a design strategy in which users "learn on demand."

The notion of learning on demand derives from several current cognitive science theories on the nature of learning—namely, that learning is a process of knowledge construction; that it is knowledge-dependent; and that it is highly tuned to the situation in which it takes place. By being learner-driven, learning on demand represents an approach fundamentally different from that of (typically system-driven) intelligent tutoring systems. Moreover, by providing support mechanisms relevant to the user's ongoing tasks, this design strategy can help the user turn "breakdown situations," or impasses, into opportunities for learning new aspects of domains, tasks, and systems.

A variety of names (learning on the job, just-in-time learning, lifelong learning) have emerged recently, all addressing similar concerns. Collectively, these approaches raise many important questions in reconsidering (1) the role of learning over the course of an individual's life, (2) the organization of learning opportunities within our society in the future, and (3) the technological environments needed to support new forms of education.

Many issues surrounding LOD in our own work are pursued in the context of developing conceptual frameworks and innovative systems for domain-oriented, programmable design environments. We believe that our approach transcends some of the limitations of open learning environments, intelligent tutoring systems, and standard "tool-based" applications. Our environments support learner control, expressiveness, assistance, modifiability, domain-oriented description, information delivery, contextualization of information to the task at hand, and collaboration between users. Our systems attempt to be particularly effective in exploiting the motivation of users by permitting learning to take place in the context of actual problem situations.

By putting the choice of tasks and goals under the control of the learner, LOD can contribute to the goal that learning should simply be a natural consequence of being alive and in touch with the world, rather than a process separate from the rest of life.

John Anderson: The Role for Basic Skills

If most job-relevant knowledge must be learned on demand what is the role for basic education? In particular, I will consider the role of a traditional high school mathematics education. There is a general perception that American children are poorly prepared in mathematics and that this is part of the reason for our lack of international competitiveness. However, the kind of mathematics that American schools fail at teaching (and which other countries excel at) has increasingly little relationship to work performance. Almost all of the mathematics that students learn in traditional high school mathematics is job-irrelevant (e.g., doing proofs in geometry) or now automated (e.g., algebraic symbol manipulation). Most people's on-the-job contact with mathematics (if they have any) will be in using tables and software packages based on mathematics. Perhaps we need only teach traditional mathematics to a small minority of the population who will maintain these systems.

Perhaps the function of a high-school mathematics education is to train students to intelligently use these mathematical artifacts. I will discuss our work at building an algebra tutoring system focused on teaching students to use spreadsheet, graphing, and symbol manipulation facilities to solve "real world" problems. Intelligent use of such artifacts requires that students have some relatively traditional skills in high school mathematics. I will discuss what some of these basic skills are and how they can be tutored.

William J. Clancey: A Situated Cognition Perspective on Learning on Demand

What does it mean to say that learning is a process of knowledge construction, that it is highly tuned to the situations in which it takes place? Two interpretations, at least, are important: The neurophysiological view is that perception and action arise together, so one's knowledge is always a new way of coordinating ways of talking, seeing, and moving, within ongoing interactions (Clancey, W.J. 1993. "Situated action: A neuropsychological interpretation" (Response to Vera and Simon), *Cognitive Science* 17, 87-117). In this sense learning is tuned to situations because our perception of what constitutes "a situation" is arising within a newly organized, adapted response. The social view is that use of tools occurs within social interactions, so the idea of a task is enlarged to be "participating as member of a community of practice" and not just fixing the margins on a paper (Lave, J. and Wenger, E. 1991. "Situated Learning: Legitimate Peripheral Participation." Cambridge University Press). Both perspectives complement a strictly cognitive, information-processing analysis of manipulating representations. We ask, "coordinating what interaction?" and "what social purposes motivate the demand?" One effect of this shift is to view individual motivation as inherently social and then to consider how tool design can foster organizational learning (for sharing and accumulating methods).

People are continually faced with new computer systems that they must learn outside of the classroom. A wide variety of sources are available to support learning on demand today: (1) on-line help (indexed by topic), (2) examples of how a system can be used (e.g., word processor documents), (3) an on-line script or "tutorial" for introducing features, (4) reusable artifacts (e.g., clip-art, stacks, and buttons in Hypercard), (5) menu descriptions (e.g., "balloon help"), (6) reference manuals, and (7) bulletin boards.

We could proceed at this level, exploring how technology like "coaching systems" can be applied. This is certainly worth doing. However, considering the larger framework of social interaction is useful before launching into tool design. Learning on demand might be approached by investigating what social uses people are making of software today. Consider these social activities:

- A researcher uses a chart to explain to the lab director how project time is allocated, to justify a salary increase.
- A secretary uses a table format in a word processor to summarize an investigation of video hardware which a researcher had requested.
- A consultant brings a simulation program on a laptop computer to a meeting to show a client what kind of tool they might use in their design projects.
- A researcher prints colored block diagrams to show another researcher how a programming language was used in a previous project.

The point of these examples is that it is difficult to separate individual curiosity or desire to learn from participation in a social setting. In such examples we find people developing their social identity by influencing rewards, promoting personal involvement in a project, demonstrating competence and contribution, and enhancing a group's status.

This analysis suggests that we not focus our investigation of learning on demand on an individual's interaction with a workstation. Instead we can study tool characteristics that enhance or frustrate an individual's actions within a group. We can investigate how tools influence what conversations occur, and how artifacts are shared and adapted to develop a genre. As a simple example, do people in a group use "stationery" or templates when writing new letters or files, or start from scratch? Consider what happens when someone creates an artifact (e.g., a hypercard stack summarizing a research project), which is not used or commented on by colleagues. In a larger sense, "learning on demand" involves constructing goals and values with colleagues. What tools might encourage such conversations to occur?

To proceed in this way, we should study what's happening in groups today—how is individual learning of computer tools embedded in social actions? What are the speech acts involved in creating representations, such as spreadsheets and diagrams, and sharing them? By this view, promoting new uses for tools goes beyond teaching how to use a tool's features for local tasks. Learning on demand can help people formulate what they are attempting to accomplish within a group, make transparent individual contributions, and establish a culture of building on each other's work.

Wally Feurzeig: Non-Directive Tutors

Abstract. Advanced technology has been extensively applied to the development of prescriptive instructional environments (tutors) at one end of the teaching/learning spectrum, and of learner-controlled instructional environments (tools, microworlds) at the other. We are advocating the development of instructional environments that integrate microworlds and tutors, called *non-directive tutors*. These learner-controlled systems incorporate both tutors and expert mathematical manipulators as integral facilities to support learning.

The user of such a system can invoke an expert aid to perform a designated mathematical operation. He can ask the tutor for advice about what operation to perform. He can also ask the tutor to critique his work and diagnose his errors or to demonstrate the working out of a new problem that he poses. He can elect to call on support from these facilities at any step during the interaction or he can decide to do the problem step on his own: the student retains the control and initiative. Nondirective tutors are valuable for supporting the development of mathematical inquiry and problem solving skills. One such system is described next.

The Algebra Workbench

Introductory algebra students have to confront two complex cognitive tasks in their formal work: problem-solving strategy (deciding what mathematical operations to perform in working toward a solution) and symbolic manipulation (performing these operations correctly.) Because these two tasks—each very difficult in its own right for beginning students—are confounded, the difficulties of learning algebra problem solving are greatly exacerbated. The key idea of the Algebra Workbench is to facilitate the acquisition of problem-solving skills by sharply separating the two tasks and providing students distinct facilities for automating each.

The program includes powerful facilities for performing the symbolic manipulations requested by a student. For example, in an equation-solving task it can add, subtract, multiply, or divide both sides of the equation by a designated expression, expand a designated term, combine terms, and so on. This enables students to focus on the key strategic issue: choosing what operation to do next to advance progress toward a solution. The program also has a variety of facilities to support students' strategic work at any point. It can provide advice on effective problem-solving steps; it can check a student's solution for errors; and it can demonstrate its own solution to a problem.

The Algebra Workbench is designed for use with formal problems in the introductory course, e.g., solving equations and inequalities, testing for equivalence of expressions, factoring, simplification, etc. It can provide a student with a set of problems or accept problems posed by the student. When it demonstrates the working out of a problem it employs pattern recognition and expression simplification methods at a level that can be readily emulated by beginning students as a model for their own work. Its facilities for expression manipulation, demonstration, explanation, advice, and critical review are available at the student's option at any time during a problem interaction.

Learner-driven systems with learner supports, like the Workbench, are invaluable for helping students acquire the knowledge and skills they need to use math. However, these tools need to be augmented by open-ended learner-driven tools—extensible design tools that enable students to undertake their own mathematical projects. Our sixth-grade algebra students used the Workbench but they also wrote Logo programs for generating gossip and poetry, making and breaking secret codes composed of functions, and a variety of other tasks with algebraically rich content in contexts that they found compelling.

Joan Greenbaum: Learning on Demand—Active Learning Strategies for the Teaching of System Development

At City University over 80% of the Computer Information Systems students are from non-English-speaking countries. Like the mosaic of New York City workplaces, these students come from a wide variety of countries bringing cultural and ethical standards that are different from traditional system development norms. To teach system development as if it were a subject to be lectured and learned is foolish under normal circumstances and absurd given the rich diversity of languages and cultures found in New York. For these reasons and others, we focus the classroom process on active learning strategies that encourage situation based learning which places emphasis on successful learners being more in charge of their learning.

Active learning strategies based on collaborative learning groups and projects are not new. Many consider these approaches to be the basis of "good learning strategies" (Mathews, "Collaborative Learning: A Sourcebook for Higher Education"), and there has been a nationwide effort to broaden the debate surrounding this approach to emphasize its importance on a college level. What is new, however, is the double emphasis of using collaborative learning strategies both to teach system developers and for system developers to incorporate in their work with users. Thus active learning takes on a dual role—the activities of the systems developers and in turn their activities with users.

In highlighting dual active learning strategies in the teaching of system development, I would like to focus on the following points:

1. Teaching system development and training users are similar in that both require learning to take place in specific contextual situations. (Suchman, "Plans and Situated Actions.")

2. Experience has shown that the more concrete and relevant the experiential base, the more motivation the learners have for carrying out the projects (Romer and Whipple, "Collaboration Across the Power Line").

3. In both systems work and in the work of users, there are pitfalls, stressful periods and times of great ambiguity. Thus users, for example, may only want to do the "local" task at hand in order to get on with their "real work" and systems students may only have the time to get the assignment done in order to get on with their other courses and interests. "Local" or sometimes fragmented knowledge is appropriate if one assumes that all active learning is an ongoing process and that the time frame of the process needs to be determined by the learners in the context of their work environment. Learning by doing can only be done in stages, and whether the learners are system developers or users, the process is ongoing, much like the system development process (Greenbaum and Kyng, "Design at Work").

John C. Thomas: Learning on Demand—Contexts of Use

One of the frustrations that curious people experience commonly is the long time lag that often occurs between the desire for some information, knowledge, or skill and its acquisition. Often, a whole series of actions, valueless in themselves, must be taken before the acquisition even begins. A second common source of frustration—rampant in formal education, but continuing into worklife—is the time spent being exposed to information, knowledge, or skills that are not of any current interest or utility to the learner.

A natural outgrowth of these experiences is the desire for Learning on Demand (LoD). While the value of this approach may seem self-evident, leaving as the only issue for discussion how to implement such a system as efficiently as possible, I would like to raise another set of issues focusing on the circumstances under which Learning on Demand makes more sense than alternative schemes. Ultimately, the resolution of these issues should be incorporated into an overall educational scheme, of which LoD is a part.

First, it should be noted that the highest levels of performance and the highest rates of improvement in performance often come about under conditions far from LoD. Consider the following relationships: director of actors in drama, mentors in business, coaches in sports, tutors in education, therapists in medicine. In all these cases, the outside expert seems to have a better insight into what is possible. The expert has both more meta-knowledge about the domain and a different attribution/ motivational scheme than the person being tutored. The greater degree of meta-knowledge means that the tutor can do a better job of task selection than can the tutee. In addition, the tutee will often stop trying to do a task, attributing failure to the intrinsic difficulty of the task or their own intrinsic lack of ability. The tutor will often refuse to accept these attributions, insisting instead that the task *is* doable with more effort or a different approach. (Note also, however, that these situations are far from those found in a typical classroom!)

On the other hand, there are situations where a purely learning on demand situation also results in great progress. For instance, masters working in such diverse fields as mathematics, music, writing, invention, and art often produce breakthroughs via prolonged and concentrated individual effort. Such situations are characterized by:

1. Explorations of new domains (e.g., Newton exploring light and calculus) where the master is creating their own meta-knowledge as they go,

2. A conviction (Edison's storage battery and electric light bulb) that the task *is* doable, and

3. A method of continuously checking results (Mozart being able to "play" music in his head).

Under this combination of circumstances, the attributional and meta-knowledge conditions are satisfied by the learner alone.

A system that would allow variations of LoD should be contingent on a number of questions. These might include:

1. What is the motivation for learning—to solve a current problem or for general education?

2. Will the information be re-used or used only once?

3. What is the level of meta-knowledge of the learner?

4. Is there a possibility of "resistance" to new learning?

5. What is the complexity of the current problem?

6. What is the emotional state of the learner?

7. How does the LoD material relate to organizational or cultural goals? (For instance, it may be in "society's interest" to ensure some common grounds for discussion).

8. Most importantly, what are the alternatives to LoD?

If the only available alternative is traditional classroom instruction, LoD may be preferable under a wide variety of conditions even for a novice. On the other hand, if individual human or computer tutoring is an option, LoD may be reserved for the highest levels of performance.

At NYNEX, we are building a hybrid system called DIME that combines ITS, hypertext, Video on Demand lectures, and multimedia teleconferencing. This system will be discussed in terms of LoD. We are also designing a trial of "talking books" which will allow students to supplement reading assignments with listening over POTS (Plain Old Telephone Systems).