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Conceptual Frameworks And Innovative Computational Environments In Support Of Self-Directed And Lifelong Learning

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Remark

This report is also available in German under the title "Möglichkeiten und Grenzen moderner Technologien zur Unterstützung selbstgesteuerten und lebenslangen Lernens".

Abstract

Wisdom is not a product of schooling,but the lifelong attempt to acquire it." — Einstein

Learning can no longer be dichotomized into a place and time to acquire knowledge (school) and a place and time to *apply* knowledge (the workplace). Today's citizens are flooded with more information than they can handle and tomorrow's workers will need to know far more than any individual can retain.

Making learning part of life is an essential challenge for inventing the future of our societies. Lifelong learning is a necessity rather than a possibility or a luxury to be considered. Self-directed learning (often occurring as learning on demand in response to breakdowns) is the dominant form of lifelong learning. This report articulates existing problems in our current and future world requiring lifelong and self-directed learning. It define conceptual frameworks, describes innovative computational environments, illustrates changing practices, and enumerates challenges.

Most current uses of technology to support life-long learning are restricted to a "gift wrapping" approach: they are used as an add-on to existing practices rather than a catalyst for fundamentally rethinking what education and learning should be about in the next century. "Old" frameworks, such as instructionism, fixed curriculum, memorization, decontextualized learning, etc., are not changed by technology itself. This is true whether we use computer-based training, intelligent tutoring systems, multimedia presentations, or the WWW. Computational media and environments need to be developed supporting "new" frameworks for lifelong learning such as: integration of working and learning, learning on demand, self-directed learning, information contextualized to the task at hand, (intrinsic) motivation, collaborative learning, and organizational learning.

The major objective of this report is to provide an overview and a critical assessment of experiences (specifically in the USA) in the use of new media in support of self-directed and lifelong learning. To achieve this global goal, the report is focused on the following more specific goals:

1. it develops a broader concept of learning;
2. it creates a coherent view of self-directed and lifelong learning by integrating theory, innovative system development, practice and assessment;
3. it defines innovatives approaches how computational media can support self-directed and lifelong learning and make it socially, technically and economically feasible;
4. it provides a description of activities and specific examples addressing these issues in the USA (including specific examples from our own work); and
5. it articulates a set of reccomendations how to pursue these themes in the future.

Keywords: self-directed learning, lifelong learning, learning on demand, collaborative learning, integration of working and learning, critiquing, breakdowns, simulation, change, symmetry of ignorance, gift-wrapping approach of using technology

Reading Guide. The report is structured by first identifying the problems (Chapter 2) which underlie the need and provide the opportunities for self-directed and lifelong learning, Chapter 3-6 discuss the four major dimensions (conceptual frameworks, innovative systems, practices and assessment, as illustrated in Figure 1). Chapter 7 give a brief overview of development s in the USA (which is elaborated in Appendix 1). Chapter 8 articulates recommendations for research (in all of the four major dimensions) to gain a deeper understanding of self-directed and lifelong learning.

Editorial Comments. The World-Wide Web has emerged a an important information repository in the USA and around the world. Throughout this report I have provided WWW addresses (URLs) to allow the reader to explore additional information relevant to this report in a self-directed fashion. The reader should be aware that some of these addresses are not stable and sustained over time. I have checked all the addresses that they were operational at the time of the writing of this report (February / March 1998).

Remarks:

1. One specific objective of this report was to identify developments (reports, research projects, publications, etc.) in the USA relevant to self-directed and lifelong learning. I have tried to enumerate and briefly describe (most of the time in the authors own words) a number of different efforts. I have obstained from evaluating these efforts with my own assesssment criteria.
2. I have chosen several specific examples from our own work in the Center for "LifeLong Learning and Design" (L3D) at CU Boulder for two reasons: (a) I know this work best, and (2) we have worked on the themes of self-directed and life-long learning for a long time.

1. Introduction

The focus of this report on themes such as self-directed learning, lifelong learning, learning on demand, collaborative learning, integration of working and learning, etc. does *not* imply that there is no need or no value associated with instructional settings with schools and universities as we know them, and with media and technologies (e.g., books, films) as we have used them. For novices in specific domains and for the spread of objective, existing and well-understood knowledge, instructionist classrooms are well suited. The attempt of this report is to show that more is needed in a world, where learning needs to become an integral part of life.

Figure 1 represents the basic structuring principle for this report: theory, innovative and intelligent systems, practices, and assessment inform each other to allow us to gain a deeper understanding of self-directed learning.

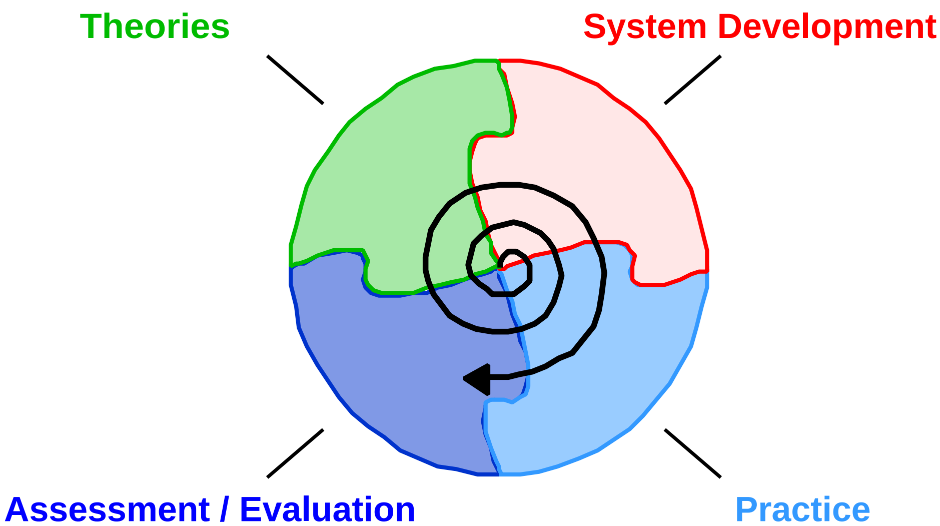

Figure 1: Integrating Theories, Innovative Systems, Practices, and Assessment

2. Problems

> "Die Erkenntnis beginnt nicht mit Wahrnehmungen oder Beobachtungen oder der Sammlung von Daten oder Tatsachen, sondern sie beginnt mit *Problemen*." (Popper)

Lack of Creativity and Innovation. Societies and countries of the future will be successful not "because their people work harder, but because they work smarter". Creativity and innovation are considered essential capabilities for working smarter in knowledge societies [Drucker, 1994] creating the important challenge how these capabilities can be learned and practiced. An implicit assumption made is that self-directed and lifelong learning can influence the creativity and innovation potential of individuals, groups, organizations, and countries.

Coping with Change. Most people see schooling as a period of their lives that prepares them for work in a profession or for a change of career. This view has not enabled people to cope well with:

- Most people change careers 3-4 times in their lives whereas what they learned in school was designed to prepare them for the first career.

- The pace of change is so fast that technologies and skills to use them become obsolete within 5-10 years. Technological literacy is a function of time. It is not sufficient to become technologically literate once (as it may be the case for reading and writing), but our knowledge about new technologies and new media needs to be evolved and updated on an ongoing basis making lifelong learning a necessity rather than a luxury.

- Many people working in supposedly secure lifetime jobs suddenly find themselves unemployed and unemployable.

- University graduates are not well prepared for work.

- Companies have trouble institutionalizing what has been learned (e.g., in the form of organizational memories) so that the departure of particular employees does not disable a firm.

- Although employers and workers alike realize that they must learn new things, they often don't feel they have the time to do so.

Our educational system of rests on several assumptions contributing to these breakdowns: (1) schooling precedes work; (2) schooling provides few skills that prepare one to solve the problems arising in life and at work; and (3) learning is not integrated into the life and work of humans, but decontextualized in separate activities.

Information is not a scarce resource. "Dumping" even more decontextualized information on people is not a step forward in a world where most of us already suffer from too much information. Instead, technology should provide ways to "say the 'right' thing at the 'right' time in the 'right' way." Information consumes human attention, so a wealth of information creates a poverty of human attention.

"Ease of use" is not the greatest challenge or the most desirable goal for new technologies. Usable technologies that are not useful for the needs and concerns of people are of no value. Rather than assuming people should and will be able to do everything without a substantial learning effort, we should design computational environments that provide a low threshold for getting started and a high ceiling to allow skilled users to do the things they want to do.

Computers by themselves will not change education. There is no empirical evidence for this assumption based on the last 30 years of using computers to change education (such as computer-assisted instruction, computer-based training, or intelligent tutoring systems). Technology is no "Deus ex machina" taking care of education. For example: making slides available over the World-Wide Web rather than giving paper copies to students can be valuable, but will not change education. Instructionist approaches are not changed by the fact that information is disseminated by an intelligent tutoring system.

The content, value, and quality of information and knowledge is not improved just because it is offered in multi-media or over the WWW. Media itself does not turn irrelevant or erroneous information into more relevant information. We must create innovative technologies (such as simulations, visualizations, critiquing, etc.) to let people "experience" knowledge in new ways.

The "Nobel Prize winner" myth: Every school child will have access to a Nobel Prize winner. This was one of the selling points for the information superhighway in the USA. While this argument is true (or will be true soon) at the level of technical connectivity, it is doubtful that Nobel Prize winners will look forward to getting a few thousand e-mail messages a day.

The single or most important objective of computational media is not reducing the cost of education. Although we should not ignore any opportunity to use technology to lessen the cost of education, we should not lose sight of an objective that is of equal if not greater importance: increasing the *quality* of education.

The 'super-couch potato' consumers should not be the target for the educated and informed citizen of the future. The major innovation that many powerful interest groups push for with the information superhighway is to have a future where everyone shows her or his creativity and engagement by selecting one of at least 500 TV channels with a remote control. The major technical challenge derived from this perspective becomes the design of a "user-friendly" remote control. Rather than serving as the "reproductive organ of a consumer society" [Illich, 1971], educational institutions must fight this trend by cultivating "designers," i.e., by creating mindsets and habits that help people become empowered and willing to actively contribute to the design of their lives and communities.

School-to-work transition is insufficiently supported. If the world of working and living (a) relies on collaboration, creativity, definition, and framing of problems; (b) deals with uncertainty, change, and distributed cognition; (c) copes with symmetry of ignorance; and (d) augments and empowers humans with powerful technological tools, then the world of schools and universities needs to prepare students to function in this world. Industrial-age models of education and work (based on Skinner and Taylor, see Figure 6) are inadequate to prepare students to compete in the knowledge-based workplace. A major objective of our lifelong learning approach is to reduce the gap between school and workplace learning.

The "Gift Wrapping" Approach Dominates Educational Reform.

"Old wine does not improve for being poured into different shaped bottles ."— J. Bruner

A deeper understanding and more effective support for lifelong learning will contribute to the transformation that must occur in the way our society works and learns. A major finding in current business reengineering efforts is that the use of information technology had disappointing results compared to the investments made in it [Landauer, 1995]. While a detailed causal analysis for this shortcoming is difficult to obtain, it is generally agreed that a major reason is that information technologies have been used to mechanize old ways of doing business (as illustrated by Figure 2)—rather than fundamentally rethinking the underlying work processes and promoting new ways to create artifacts and knowledge.

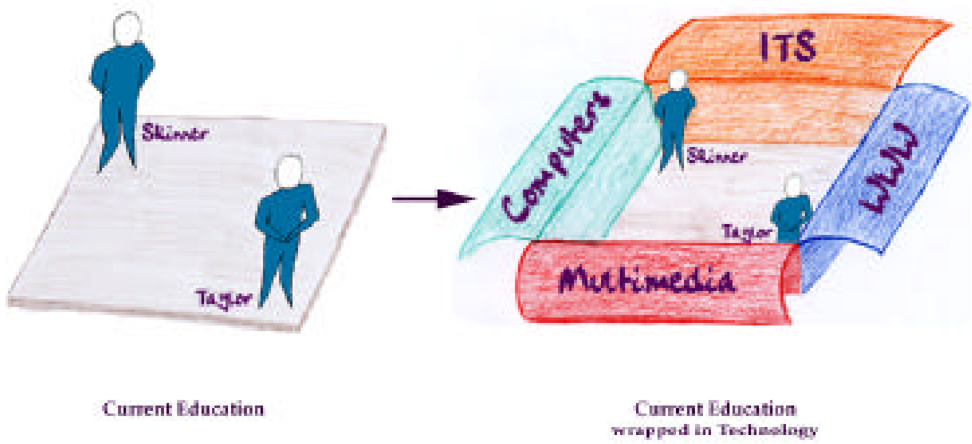

Figure 2 : The Gift Wrapping Approach: Adding Technology to Existing Educational Practice

We claim that a similar argument can be made for current uses of technology in education: it is used as an add-on to existing practices rather than a catalyst for fundamentally rethinking what education should be about in the next century. For example, the "innovation" of making transparencies available on the World-Wide Web (WWW) rather than distributing copies of them in a class takes advantage of the WWW as an electronic information medium. This may change the economics of teaching and learning, but it contributes little to introducing new epistemologies. Old frameworks, such as instructionism, fixed and "balkanized" curricula, memorization, decontextualized rote learning, etc., are not changed by technology itself. This is true whether we use computer-based training, intelligent tutoring systems, multimedia presentations, or the WWW. Education all too often follows on the boot heels of technology rather than guiding the appropriate development and use of technology.

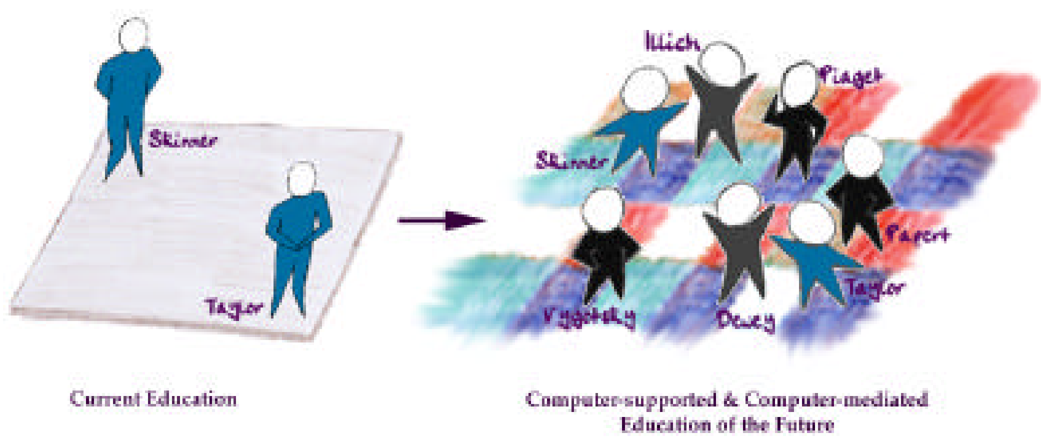

Figure 3: Rethinking, Reinventing and Redesigning Educational Theory and Educational Practice

We need computational environments to support new frameworks for education such as lifelong learning, integration of working and learning, learning on demand, authentic problems, self-directed learning, information contextualized to the task at hand, (intrinsic) motivation, collaborative learning, and organizational learning. Figure 2 illustrates the "gift-wrapping" approach in which technology is merely wrapped around old frameworks for education. Figure 3 indicates what is needed instead: a richer conceptual framework, leading not just to the addition of technology but to the rethinking, reinventing and redesigning of learning and working using innovative media and technologies.

Moving beyond the "gift-wrapping approach" implies that

- we explore the fundamentally new possibilities and limitations of computational media on how we think, create, work, learn, and collaborate. It simply isn't good enough to spend money on new technologies and then to use it in old ways. New tools will not just help people do cognitive jobs more easily but in the same way they used to, but they will also lead to fundamental alterations in the way problems are solved.
- we change mindsets, e.g., seeing and understanding breakdowns and symmetry of ignorance as opportunities rather than as things to be avoided, and
- teachers understand their roles not only as truth-tellers and oracles, but as coaches, facilitators, mentors, and learners.

3. Conceptual Frameworks

3.1 Survey and Brief Analysis of Modern Learning Theories

Current trends in educational theory make the following fundamental assumptions about *learning* [Resnick, 1989]:

- Learning is a process of **knowledge construction**, not of knowledge recording or absorption [Harel & Papert, 1991] (i.e., the learner's mind is not passive, not a receptacle to be filled) —requiring environments in which learners can be active designers and contributors rather than passive consumers. Research in end-user programming and end-user modifiability contributes toward this goal.
- Learning is **knowledge-dependent**; people use their existing knowledge to construct new knowledge—requiring environments supporting user-tailored information presentations such as differential descriptions of new information (for example: if someone wants to learn HTML and knows MS-WORD, the explanations and examples provided should be different than those given to a learner who knows Framemaker).
- Learning is highly **tuned to the situation** in which it takes place [Lave & Wenger, 1991] — requiring environments which are domain-oriented and which support human problem-domain interaction and not just human computer interaction . The information spaces presented and the information provided should be made relevant to the task at hand, something which computational media can achieve, but which is impossible for paper and pencil technologies.
- Learning needs to account for **distributed cognition** [Norman, 1993] requiring — requiring environments which create and define new role distributions between humans and computers. Most of what any individual "knows" today is not in her or his head, but is out in the world (e.g., in other human heads or embedded in media). Humans are tool-using, tool-making species; we rely on culturally devised ways of thinking, learning, working and collaborating.

Pure memory and pure thought are fictions, occasionally useful, but fictions nonetheless [Bruner, 1996].

- Learning is affected as much by **motivational issues** [Csikszentmihalyi, 1990] as by cognitive issues — requiring environments which let people experience and understand why they should learn and contribute something. For example, learning-on-demand lets users access new knowledge in the context of actual problem situations and delivers information about which they are unaware in the context of *their* problem situations. Environments must allow users to take pride in their contributions and be awarded for them.

3.2 Self-Directed Learning in the Context of Modern Learning Theories

Lifelong Learning. Lifelong learning needs to promote effective educational opportunities in the many learning settings through which people pass. As shown in Figure 4, these settings include home, school, work, and the larger political community, or *polis*. The branching lifeline running through these settings in the figure represents the multiplicity of roles (member of a family, student, worker, voter) that a person assumes in varying combinations during life.

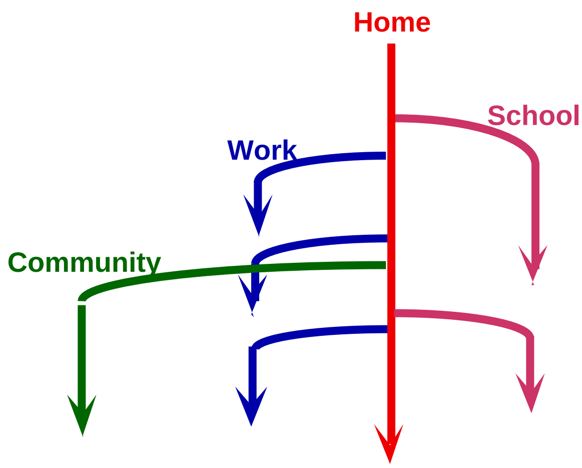

Figure 4: Several of the Paths of Lifelong Learning

Learning needs to be examined across the lifespan because previous notions of a divided lifetime—education followed by work—are no longer tenable[Gardner, 1991]. Professional activity has become so knowledge-intensive and fluid in content that learning has become an integral and irremovable part of adult work activities. Learning is a new form of labor [Zuboff, 1988] and working is often (and needs to be) a collaborative effort among colleagues and peers. In the emerging knowledge society, an educated person will be someone who is willing to consider learning as a lifelong process. More and more knowledge, especially advanced knowledge, is acquired well past the age of formal schooling, and in many situations through educational processes that do not center on the traditional school [Illich, 1971].

Professional work cannot simply proceed from a fixed educational background; rather, education must be smoothly incorporated as part of work activities. Similarly, learning takes place not only at all ages and in virtually all professions; increasingly, it takes place among heterogeneous groups of people in families, clubs, and virtual communities. Insights gained from these individual situations needs to be developed into broad and effective theories of learning, innovative and intelligent systems, practices, and assessment across many professional genres. A lifelong learning approach permits integration of the best features of school, community, home, and workplace learning.

A theory of lifelong learning must investigates new approaches to learning required by the profound and accelerating changes in the nature of work and education. These changes include

(1) an increasing prevalence of "high-technology" jobs requiring support for learning on demand because coverage of concepts is impossible; (2) the inevitability of change in the course of a professional lifetime, which necessitates lifelong learning; and (3) the deepening (and disquieting) division between the opportunities offered to the educated and to the uneducated.

Lifelong learning is a continuous engagement in acquiring and applying knowledge and skills in the context of self-directed problems and should be grounded in descriptive and prescriptive goals such as:

- learning should take place in the context of authentic, complex problems (because learners will refuse to quietly listen to someone else's answers to someone else's questions);
- learning should be embedded in the pursuit of intrinsically rewarding activities;
- learning-on-demand needs to be supported because change is inevitable, complete coverage is impossible, and obsolescence is unavoidable;
- organizational and collaborative learning must be supported because the individual human mind is limited; and
- skills and processes that support learning as a lifetime habit must be developed.

Self-directed Learning. Most learning taking place outside of an (instructionist) classroom can be characterized as follows: humans are engaged in some activity (some action such as working, collaboratively solving a problem, or playing), they experience a breakdown and they reflect about the breakdown (i.e., the piece of lacking knowledge, the misunderstanding about the consequences of some of their assumptions, etc.). Schön [Schön, 1983] calls this reflection-in-action. Because self-reflection is difficult, a human coach, a design critic, a teacher can help the learner to identify the breakdown situation and to provide task-relevant information for reflection. In our own work, we have explored the possibility using computational critics [Fischer et al., 1993] to provide some of this support when humans are not present. Critics make argumentation serve design, i.e., they support learners in their own activities.

This brief characterization illustrate how self-directed learning differs from *intelligent tutoring systems* (where the problem is given by the teacher or the system) and *interactive learning environments* (such as LOGO [Papert, 1980]) where no support is given when a learner is stuck. Interactive learning environments support autonomous learning; in order to support self-directed learning they need to be augmented with mechanism that can offer help, support, reflection for learners who get stuck or who do not know how to proceed.

Engagement and support for self-directed learning is critical when learning becomes an integral part of life — driven by our desire and needs to understand something, or to get something done instead of solving a problem given in a classroom setting. A lifelong learning perspective implies that schools and universities need to prepare learners to engage in self-directed learning processes because this is what they will have to do in their professional and private lives outsides of the classroom.

It is advantageous for both motivation and the ability to acquire new knowledge that students be able to direct their own learning [Fischer, 1991]. Self-directed learning de-emphasizes teaching as a process in which a teacher tells something to a passive learner, but focuses instead on mutual dialogs and joint knowledge construction which is enhanced by the creation, discussion and evolution of artifacts.

Many industrial training programs assume forms of self-directed learning [Scribner & Sachs, 1990], in which workers are given a brief introduction to a complex, computer-controlled system, and are then expected to complete their training on the job. As the stage of life and background knowledge of learners, as well as their goals, become increasingly varied, the need for self-directed learning will become even more important.

Informal and Formal Learning Perspective. Self-directed learning can be further characterized in comparison to a informal and formal learning perspective [Norman, 1993] as illustrated in Figure 5.

Informal Learning	**Formal Learning**
unstructured	structured
a group or joint activity	an individual activity
the goal is motivated from the learner's point of view	the goal is not well motivated from he student's point of view
the activity is captivating fun	“fun” is not a relevant consideration
there are frequent “flow” experiences	there are seldom any “flow” experiences
the activities are self-paced	the activities are fixed, force-paced
the person has a choice of topic, time and place	the topics are fixed, as are time and place
the activities can be done throughout life in many environments	the activities are primarily restricted to ages 6-20+ in a schoolroom
discretionary	forced

Figure 5: Informal versus Formal Learning

3.3 Beyond Skinner and Taylor

Many conventional frameworks of learning (programmed instruction, computer-based training) and working (a best scientific way) are grounded in the behaviorist learning theory of B.F. Skinner and the models of industrial work of F.W. Taylor. Figure 6 contrasts these approaches with the lifelong and self-directed approaches to learning.

Skinner/Taylor		**L^{3}D**
there is a "scientific," best way to learn and to work (programmed instruction, computer-assisted instruction, production lines, waterfall models)	--->	**real problems are ill-defined and wicked; design is argumentative, characterized by a symmetry of ignorance among stakeholders**
separation of thinking, doing, and learning	--->	**integration of thinking, doing, and learning**
task domains can be completely understood	--->	**understanding is partial; coverage is impossible**
objective ways to decompose problems into standardizable actions	--->	**subjective, situated personal interests; need for iterative explorations**
all relevant knowledge can be explicitly articulated	--->	**much knowledge is tacit and relies on tacit skills**
teacher / manager as oracle	--->	**teacher / manager as facilitator or coach**
operational environment: mass markets, simple products and processes, slow change, certainty	--->	**customer orientation, complex products and processes, rapid and substantial change, uncertainty and conflicts**

Figure 6: Beyond Skinner and Taylor

3.4 Integration of Working and Learning

"A major illusion on which the school system rests is that most learning is the result of teaching" — Illich

Learning is part of living, a natural consequence of being alive and in touch with the world, and not a process separate from the rest of life. What learners need, therefore, is not only instruction but *access* to the world (in order to connect the knowledge in their head with the knowledge in the world) and a chance to play a meaningful part in it. Education should be a distributed lifelong process by which one learns material as one needs it. School learning and workplace learning need to be integrated. I refer to workplace learning not as it is currently practiced (i.e., companies imitating school learning by sending their employees to decontextualized classrooms), but as it could be or should be. An assessment of the effectiveness of workplace learning as it is currently practiced is characterized by the following observation: "American business have a major stake in fostering transfer of training, since they spend up to a $ 100 billion each year to train workers. Yet the estimate is that no more than 10% of training transfers to the job. So business wastes $90 billion each year because of lack of transfer." [Detterman & Sternberg, 1993].

Examples of what workplace learning could be or should be include apprenticeship-style relationships, such as internships for doctors and Ph.D. students. In such learning situations, problems are not given, but need to be framed. Collaboration is critical and learning is firmly integrated with working. Figure 7 compares school and workplace learning along a number of dimensions.

	Schools	**Workplace**
EMPHASIS ON:	"basic" skills	education embedded in ongoing work activities
POTENTIAL DRAWBACKS:	decontextualized, not situated	important concepts are not encountered
PROBLEMS ARE:	given	constructed
NEW TOPICS:	defined by curricula	arise accidentally from work situations
STRUCTURE:	pedagogic or "logical" structure	work activity
ROLES:	expert-novice model	reciprocal learning
TEACHERS/ TRAINERS:	expound subject matter	engage in work practice
MODE:	instructionism (knowledge absorption)	constructionism (knowledge construction)

Figure 7: A comparison of school and workplace learning

3.5 Self-directed Learning, Reflection-in-Action and Breakdowns

As mentioned before, reflection-in-action [Schön, 1983] (or making argumentation serve design [Fischer et al., 1996]) provides an interesting conceptual framework for self-directed learning. Erasing the distinction between learning and working allows us to design learning, teaching and education media and technologies in entirely new ways. The way we learn is trying something, doing it and getting stuck. In order to learn, we really have to be stuck, and when we're stuck we are ready for the critical piece of information. The same piece of information that made no impact at a lecture makes a dramatic impact when we're ready for it.

The Centrality of Breakdowns. The work of organizations is riddled with breakdowns — disruptions, interruptions, dead ends, incompletions, missed communications, unforeseen circumstances, obstacles, impasses, external events, and unexpected opportunities. Coping with breakdowns is essential, for otherwise no work would be done. If a problem or crisis arises, workers must undertake to fix it; after solving the problem they may stop to reflect and ask whether they could restructure any process so as to avoid that breakdown again; they learn individually from the breakdown and, after restructuring the process, so does the organization.

The workplace model of coping with breakdowns can be characterized as an action-breakdown-repair or as reflection-in-action model in which critics signal breakdown situations [Fischer, 1994b]. Workers will continue to act from existing knowledge, without thought, until they realize that they cannot go further. They stop to reflect on the problem, choose new action, overcome the breakdown, and resume non-reflective action. This differs from pre-planning (which assumes that everything can be known in advance and then acted on without breakdown) and from post-mortem analysis done during a pause or review session (where workers may reflect again to see if they can avoid recurring breakdowns by restructuring a process). Ordinary schooling is a form of pre-planning; it does not teach students how to cope with breakdowns while working and during post-mortem analyses. Self-directed learning in response to breakdowns is the most promising model to address the needs of lifelong learning.

The notion that most of what we learn is in response to breakdown has far-reaching consequences. What are "basic skills" in a world where most job-related knowledge is learned "on demand" in response to breakdowns? Tutoring systems don't fit well with the notion of learning from breakdowns. Tutoring systems show basic concepts and skills of a domain by offering the students paths through a problem-space in which the problems are well-defined and have definite answers. Problems encountered as workplace breakdowns are ill-defined (in fact, defining them as problems is part of the resolution of the breakdown), and often not anticipated. Open learning environments are somewhat better because the user calls up help as needed and in context.

This conceptual framework has led to a set of requirements for systems that help people cope with breakdowns in the context of self-directed learning. The further elaboration of this framework, the development of innovative cmputational environments to support it, the influence on new practice and a careful assessment (see Figure 1) are the objective of numerous current research efforts in the USA (see Appendix 1). The requirements can be summarized briefly as follows:

- Users set most of the goals, not the system.
- The vocabulary, tools, functions, and practices supported by the system come from the working environment, where they are natural and appropriate.
- The mode of operation emphasizes learning from breakdowns and from fulfilling commitments.
- Tools must appear directly relevant to help with the problem at hand; they must not generate further breakdowns.
- Although the system may have some built-in expertise, users will find most expert knowledge by locating other people (or their records) who have the knowledge.
- Some of the tools must help with cross-domain searching: finding similar problems that have been solved elsewhere and reporting on their solutions.
- The systems should aid users in two kinds of reflection — immediate, to deal with the problem and to organize a solution; and post-mortem, to see if the problem is recurrent and can be avoided by restructuring work processes.
- Systems should feature many interactions among people, since these are the sources of most breakdowns.
- Systems should support not only the individual's solo performance, but work in cooperation with others and while belonging to different groups at the same time: systems should support the improvement of collective knowledge as well as individual knowledge.

3.6 Symmetry of Ignorance—A Source of Opportunity for Self-Directed Learning

"The clashing point of two subjects, two disciplines, two cultures ought to produce creative chaos." C.P. Snow

Learning is more than being taught [Illich, 1971]. Teaching is often "fitted into a mold in which a single, presumably omniscient teacher explicitly tells or shows presumably unknowing learners someting they presumably know nothing about" [Bruner, 1996]. A criticial challenge is a reformulation and reconceptualization of this impoverished and misleading conception.

While this model may be more realistic for the early grades in schools [E.D. Hirsch, 1996], it is obviously inadequate for learning processes as they occur in lifelong learning, where knowledge is distributed among many stakeholders and "the answer" does not exist or is not known. Group discussions, conversations around dinner tables, and classrooms have the potential to be places where knowledge is created and constructed by communities of mutual learners.

The following figures try to illustrate this conceptual and organizational change of fundamental importance to self-directed and lifelong learning:

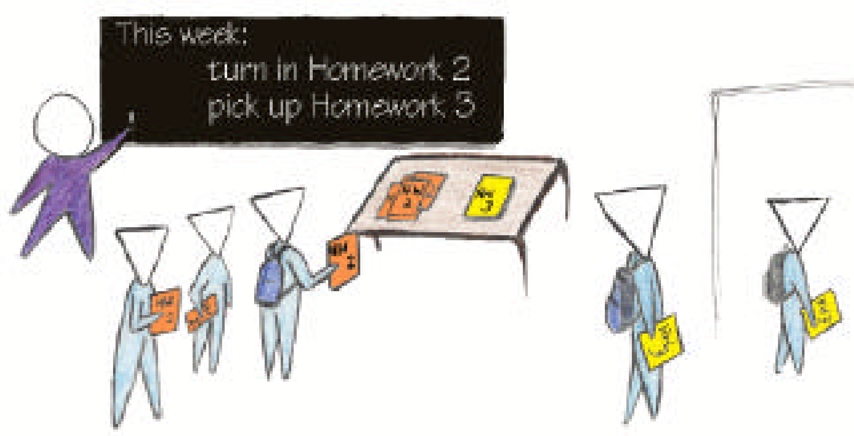

Figure 8-1: Students Solve the Same Assigned Problem —*Teacher is "the Sage on the Stage"*

Figure 8-1 illustrates the currently dominant model: students solve a problem defined by the teacher. In this model the work of the teachers scales reasonably well, because in cases where they have to deal with more students they need to grade answers to the *same* problem.

Figure 8-2: Students Solve Their Own Problems —*Teacher is "the Guide on the Side"*

In Figure 8-2 the students engage in self-directed learning activities and solve their *own* problems. Such a situation creates new demands for the teachers: (1) they may encounter problems which are new to them and the answers may be far from obvious (i.e., the teachers themselves may to have engage in substantial learning processes to understand the students' work); and (2) in this situation more solutions imply considerable more work and engagement, because additional answers will in general deal with different problems.

Figure 8-3: Students' Problems and Solutions Are Collected in a Catalog

Figure 8-3 extends Figure 8-2 that the work of the students is collected in a group memory (e.g., to be used as starting points, stepping stones or cases for later student generation). This approach supports the concept of "courses as seeds" [Fischer, 1997]. The courses-as-seeds idea provides a direction for exploration in many areas of lifelong learning in which communities of practice engage collaboratively in the incremental construction of knowledge [Scardamalia & Bereiter, 1994] in the context of a course. It provides a model for learning in a knowledge society that is built upon distributed cognition, articulate learners, peer-to-peer learning, and incremental enhancement of information spaces by a community of practice.

"Courses as seeds" can be contrasted against *"courses as finished products"* (the model currently practiced by most institutions), which exhibits the following characteristics:

- a course is offered in a (distance) learning environment and learners answer problems given to them in the course by the instructor;
- the course is given over a period of years, more or less in the same form;
- the learners are recipients of knowledge (the assumption is that the teacher / instructional designer has all the relevant knowledge);
- from time to time the teacher / instructional designer will incorporate new ideas into the course so the course doesn't become outdated; and
- this model is adequate for courses in which the learners are getting into a new field and therefore might have little to contribute.

In contrast, the *"courses as seeds"* model is built upon the following characteristics:

- a course is considered as a seed, and it is offered to a community of practice that is interested in learning new material; many of the course participants are knowledgeable people in their own working environments;
- the learners are not just passive recipients of knowledge, but active contributors; and

- at the end of the course, the content of the course will be greatly enriched through a semester or year- long interaction of knowledgeable people, and important and relevant addition will be incorporated into the course before it is taught the next time.

The *values added* by the "courses as seeds" approach include:

- it is a model for learning in a knowledge society that is built upon articulated learners forming and engaging in a community of practice;
- it is important for students to gain experience in such processes;
- such an approach is a necessity for many domains and aspects of lifelong learning where communities of practice engage in the incremental construction of knowledge facilitated by a teacher; and
- it exploits unique aspects of computational and communication media.

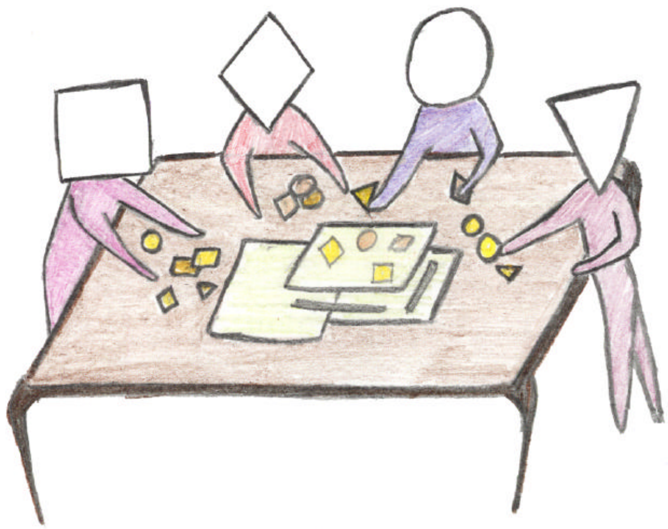

Figure 8-4: Mutual Competency and Symmetry of Ignorance

Figure 8-4 characterize learning situations in which no participants takes the role of a teacher. Historically, the role of a teacher and a learner was associated with a person. In today's world, being a teacher or being a learner is only associated with a specific context. "Official" teachers should feel comfortable to become learners in many situations. **Mutual competency and symmetry of ignorance, supported by objects-to-think-with (externalizations of ideas, concepts, and goals), leads to settings and opportunities for learning by all participants.** This is most obvious in the context of design activities. Design is collaborative in nature. The relevant knowledge to engage in a design task is distributed among stakeholders and often a "symmetry of ignorance" exists among stakeholders. Communication breakdowns are experienced because each stakeholder belongs to different work cultures, which use different norms, symbols and representations. Rather than viewing this symmetry of ignorance as an obstacle during design, it should be seen as an opportunity for creativity. Having different viewpoints helps one discover alternatives and uncover tacit aspects of the problem to cope with.

4. Innovative Computational Environments

Addressing the demands of lifelong and self-directed learning will require the development of new, innovative computational media and environments informed by the theoretical developments described in the previous section.

4.1 Examples

Examples of innovative intelligent systems that support self-directed and lifelong learning include:

- powerful substrates that provide the foundations for creating new learning applications;
- domain-oriented design environments that empower human creativity by providing features such as critiquing, simulation, self-evaluation, and resource and component discovery;
- technologies that enhance the WWW as a medium in support of learning;
- systems that allow the integration of physical and computational worlds in order to provide learning opportunities that didn't exist before;
- tools that perform assessment tasks by automatically analyzing and evaluating written products; and
- tools that can support the creation and search of organizational memories.

Substrates. Substrates are high-level system development environments that support the creation of complex, open, and "evolvable" systems. Agentsheets [Repenning, 1994] is an example of an existing substrate that can be used to develop educational interactive SimCity™-like simulations. Agentsheets' visual programming approach allows a wide range of users, including middle-school students and teachers, to create these simulations in the context of self-directed learning, rather than being confined to a consumer role of dealing what already exists.

Figure 9 illustrates the relationship between learning on demand from a system and the simultaneous need to add knowledge to the system. In many situation, learners / users do either not have the necessary skills, the time or the patience to compose programs using low-level primitives. The design of end user programming environments is critical for self-directed learning and it requires the understanding of the intricate relationships among people, tools, and problems. End users require domain-oriented design environments that elevate the task of programming to the manipulation of components that are directly pertinent to tasks at hand.

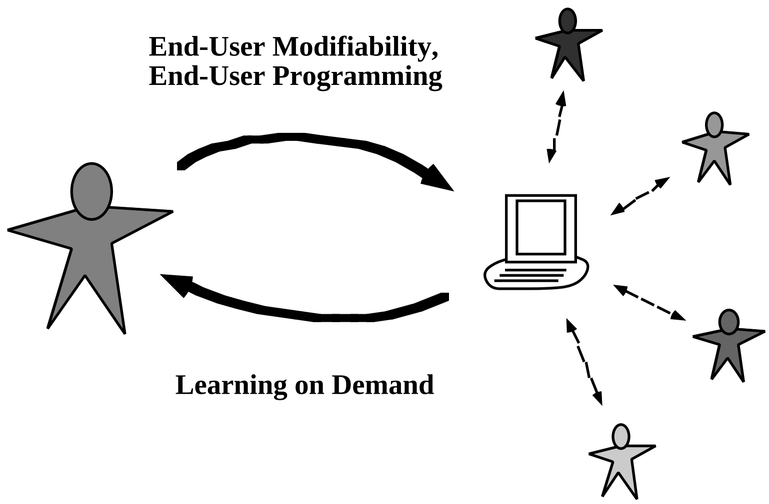

Figure 9: Learning on Demand and End-User Modifiability

Domain-oriented design environments . Domain-oriented design environments [Fischer, 1994a] can be built from appropriate substrates and support the design and construction of artifacts. They provide learning opportunities while working through mechanisms such as critiquing, catalogs of existing designs, argumentation, and end-user modifiability. Design environments not only can be used to instruct novice designers, they also are able to support designers as lifelong learners.

Environments to support mutual learning and to create shared understandings. Tools that integrate physical and computational worlds allow users to manipulate objects in one world in order to produce an effect in another and *vice versa*. The Envisionment andDiscovery Collaboratory [Arias et al., 1997] is an environment that combines physical game boards with computational simulations in order to support group decision-making processes, mutual learning processes and the creation of shared understanding. The incremental design and construction of an externalized world provides for all involved stakeholders numerous opportunities for self-directed learning.

Organizational Learning and Organizational Memories. *Organizational learning* focuses on recording knowledge gained through experience (in the short term), and actively making that knowledge available to others when it is relevant to their particular task (in the long term). A central component of organizational learning is a repository for storing knowledge in an organizational memory. However, the mere presence of an organizational memory system does not ensure that an organization will learn. Today, information is not a scarce commodity; the problem is not just to accumulate information, but to deliver the *right* knowledge at the *right* time to the *right* person in the *right* way.

For sustained organizational learning, three seemingly disparate goals must be served simultaneously. Organizational memory must be (1) extended and updated as it is used to support work practices; (2) continually reorganized to integrate new information and new concerns; and (3) serve work by making stored information relevant to the new task at hand. Organizational learning is a continuous cycle in which organizational memory plays a pivotal role:

- Individual projects serve organizational memory by adding new knowledge that is produced in the course of doing work, such as artifacts, practices, rationale, and communication.

- Organizational memory is sustained in a useful condition through a combination of computational processes providing information and people actively contributing.
- Organizational memory serves work by providing relevant knowledge when it is needed, such as solutions to similar problems, design principles, or advice.

The intimate relation between organizational memory and work practice implies that the contents of organizational memory must be easily accessible within the context of work. Computational support for organizational learning, therefore, must tightly integrate tools for doing work with tools for accessing the contents of organizational memory.

4.2 The World-Wide Web (WWW)

To support self-directed learning, we need new conceptualizations of the world-wide web. Traditional Web-based use and instruction engages the Web as a Broadcast Medium (Figure 10, Model M1). Instructional information is placed on static Web pages and there is little opportunity for learners to interact with the information. Many Web sites are evolving into a form that combines Broadcast with Feedback (M2). In the process of exploring such an information space, learners can provide feedback and ask questions via email or by filling out forms.

An essential requirement for self-directed learning is to support a third model for the Web: evolutionary and collaborative design (M3). In this model, users can use the Web to collaborate on projects, perform in-depth research on certain aspects of a project, and learn from their peers.

The M3 model poses a number of technical challenges, including the ability (1) to add to an information space without going through an intermediary, (2) to modify the structure of the information space, (3) to modify at least some of the existing information, and (4) to make argumentation contained in the information space serve design by integrating the discussion about the design into the information space itself (the latter requirement extends related research activities such as [Scardamalia & Bereiter, 1994]).

Technologies that enhance the WWW as a medium that supports self-directed learning include (1) *object repositories* to assist the creation and sharing of educational resources on the WWW, and (2) *tools for intelligently locating learning resources* that support individual learners based on their background knowledge. Existing object repositories include the Agentsheets Behavior Exchange [Repenning & Ambach, 1997] a WWW site that allows Agentsheets developers to exchange entire simulations and individual simulation components; and the Educational Object Economy, a shared repository of interactive, educational applications supported by Apple Computer, Inc. and a consortium of companies and universities including CU Boulder. These object repositories will have to be enhanced in order to support not only the discovery of relevant objects, but also the reuse and modification of these objects. Some of the tools that assist individual learners by providing the discovery of relevant learning materials will be based upon latent semantic analysis to carry out conceptual, content-based retrieval.

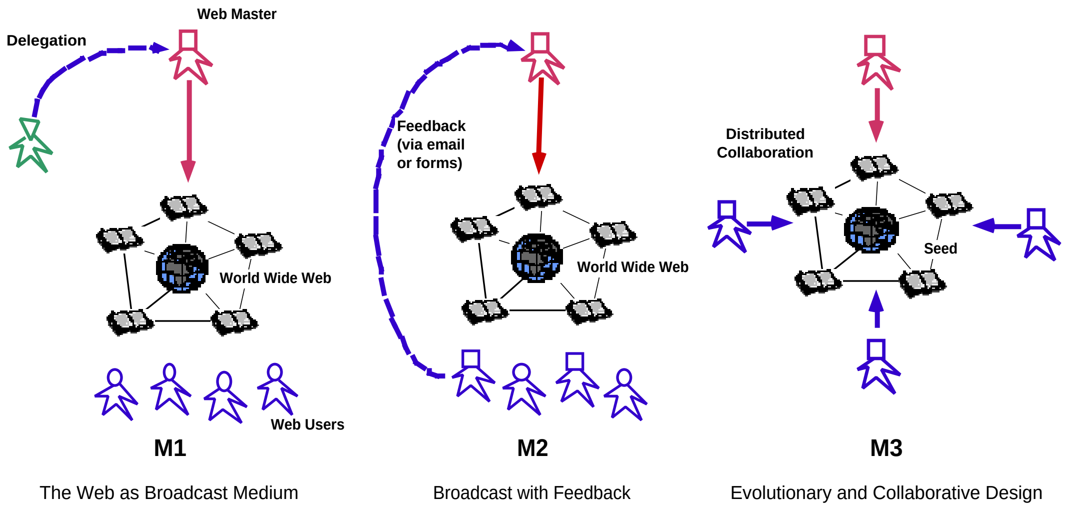

Figure 10: Making the World Wide Web a Medium for Collaborative, Evolutionary Design

In our research work, we have explored a number of prototypes and computational substrates to make the WWW an information environment more supportive of self-directed learning:

1. **Dynasit**e is a substrate for dynamic and evolvable web-based information spaces. Dynasites investigates computational support for collaborative working and learning. One of the theoretical foundations for Dynasites is collaborative knowledge construction, which postulates that information spaces supporting collaborative work and learning should grow and be shaped over time by the people who use them. The Dynasites Substrate is a collection of tools for building Dynasites Information Spaces. Dynasites information spaces are websites because they viewed through a web browser. Dynasites differ, however, from most websites because they are dynamic and evolvable by users .DynaSites information spaces are dynamic because their pages are built at "view time. Typical web sites are static - their links and displays are determined at design time (http://www.cs.colorado.edu/~ostwald/home.html>

2. **Visual Agentalk and Behavior Exchange** are system components that allows Agentsheets developers to exchange entire simulations and individual simulation components; systems (http://www.cs.colorado.edu/~l3d/systems/agentsheets/).

3. **WebQuest** [Perrone et al., 1996] a system combining the WWW with an interactive quest game thereby avoiding that students get "hyper-tracked" in self-directed learning (http://www.cs.colorado.edu/~corrina/mud/).

4. **Latent Semantic Analysis:** is a psychological theory of knowledge. It implies a particular view of language comprehension that has important theoretical consequences and affords rich possibilities for self-directed learners. It provides the foundation for one of our current research projects to help learners of all ages to become more articulate [Landauer & Dumais, 1997].

4.3 Exploiting the Unique Possibilities of Computational Media for Self-Directed Learning

"You cannot use smoke signals to do philosophy. Its form excludes the content"
(Postman, "Amusing Ourselves to Death", p 7)

Printed media and the widespread human ability to read and write are foundations on which our current societies are built. An important question to be asked is: "Will computational media cause a change of a similar magnitude compared to our society moving from an oral to a literary society" (and Socrates and Plato were arguing about the trade-offs associated with this change) or when Gutenberg's printing press eliminated the scribes and gave everyone the opportunity to become literate? The fact that societies have often overestimated change in the short run and underestimated it in the long run suggests that we should make every effort to understand the long-term societal impacts computational media.

What are unique properties of computational media which are absent in principle of printed media? And why are these properties important for self-directed learning?

Printed media do not have interpretive power — they can convey information to us, but they cannot analyze the work products created by us. Critiquing (examples are (1) spelling correctors and (2) domain-oriented design environments; see Appendix 1) is a process which *analyzes our work products* (created in the context of self-directed learning processes) and thereby increase the "back-talk" of an artifact by presenting a reasoned opinion about it. Computational media can make information relevant to the task at hand thereby reducing the information overload problem or the need for decontextualized learning. This principle can be illustrated by the current generation of help systems: while Microsoft-Word's "Tip of the Day" provides us with a piece of decontextualized information, few help systems (except for knowledgeable peers are around) which provide us with information (explicitly asked for or volunteered) relevant to a breakdown situation in our activity.

Current generation of computational environments fall short in many ways to support humans in their activities (because they are used in a "gift-wrapping" mode). People are forced to focus on the computer, rather than on their tasks. Environments are needed which support "human problem-domain interaction" rather than just "human computer interaction" ; they need to be "ready-to-hand" meaning that for members of a community, they disappear as a separable object of observation and become an integral part of their practice. Self-directed learning will also transcend the boundaries of any closed system, making mechanism such as end-user modifiability and end-user programming a necessity rather than a luxury.

5. Practice

"You must be the change you wish to see in the world" — Gandhi

The history of our practices speaks more truly than our slogans. To gain a deep understanding of self--directred learning, we must apply it to ourselves and to our institutions.The *self-applicability* of our research to our work is a critical assessment of its viability. In this section, three of our research projects are presented: (1) to explore the *changing role* of the teacher, (2) to use *working shops* as an effective means to allow teachers to become lifelong learners, and (3) to explore self-directed learning in the context of community organizations.

5.1 The Changing Role of the Teacher —Teachers as Lifelong Learners and Students as Teachers

In lifelong learning where self-directed learning plays a critical role and the learning of new material is often driven by the work to be accomplished, the problems and the questions do not originate with the teacher but with the learner. And in the world of today, where no renaissance scholars exist anymore, all of us (including teachers) need to be learners in most situations. In learning communities of the past, the role distinction between teachers and learners was tied to persons whereas in today's world it has become an attribute of a context.

As illustrated in Figure 8-1 to 8-4, teachers should not think of themselves as truth tellers and oracles, but as error detectors, coaches and facilitators who extend the intelligence of the students by helping them identify and reduce the misunderstandings and mistakes in their knowledge and skills. Teachers should feel comfortable in front of students to "be caught" not knowing something. Seeing a teacher struggling with understanding something could be one of the most important learning experience of a student, but it is too often avoided, because teachers do not feel comfortable in the roles of learners.

There are numerous situations where learners can become teachers. While this can and should happen in school settings (for example, a student knowing a lot about a particular computer application), it is the fundamental empowering aspect of communities of practice and collaborative work practices [Nardi, 1993]. The articulate learner is a teacher (a contributor of knowledge), as illustrated for example by work in Webquest. In our envisioned learning communities, learners help each other learn, but such an approach excludes by no means the presence of someone serving in the role of teacher.

5.2 Working Shops — An Environment for Teachers to Engage in Self-Directed Learning

Teachers are the ultimate change agents [Guzdial & Weingarten, 1995] (see also: <http://www.cc.gatech.edu/gvu/edtech/nsfws/>). Creating new paradigms for learning requires teachers who understand and are committed to the improvements envisioned. Teachers—more than other members of our society—need to be lifelong learners. We are in the process of developing a new concept entitled *working shops* which views teachers as lifelong learners who learn about new aspects of learning, teaching, and innovative use of technology in the context of their work, exploiting specifically possibilities that they can learn most readily from each other.

In the context of our collaboration with schools in the Boulder Valley school district, we have studied not only the application of technology to learning, but the organizational aspects of learning, as well. Widespread experience in educational reform demonstrates that how people learn and the context of learning are as important as what they learn. Creating an environment to support teachers as self-directed learners, then, requires us to examine how teachers as professional practitioners can make effective use of the rich individual and collective experiences, outside resources, new information, and the environment itself to support and enhance student learning.

Working Shops involve a regular, continuous meeting of colleagues who, sharing diverse experiences and ideas, learn together in the process of doing meaningful work. Working shops provide a indistinguishable mix of acquiring and applying knowledge, focused around the creation of concrete products that are valued by those in the shop and, ultimately, the larger community.

5.3 Boulder County Healthy Community Initiative

The Boulder County Healthy Communities Initiative is an on-going grassroots effort of several hundred stakeholders thinking about building healthy and more sustainable communities today and for generations to come in the Boulder County region of Colorado. At the moment, the Initiative’s main challenge is an educational one: how to translate its mission to all citizens, enhance its visibility, and recruit a broader and more diverse participation (e.g., school children, elderly, gender and race minorities, rural population) in order to extend and expand the ideas of its vision with new knowledge, and in a manner that is itself sustainable—where citizens learn (on demand) about relevant knowledge, design the future, and gain ownership of the ideas and developments.

An initiative of this kind founded in community participation provides an ideal environment to foster and analyze self-directed learning and investigating numerous interesting questions, such as: “Can technology support this learning process, so that more citizens can be informed participants in policy making ?”

6. Assessment

Assessment has long been a challenge in educational reform. With few exceptions, a large fraction of the educational technology systems that have been developed and promoted have never been assessed in a completely adequate manner; too often evaluation has gone no farther than verifying that students or instructors like the novel system. This is an unfortunate state of affairs for two reasons. First, it precludes the development of truly effective techniques through needed design-test cycles (see Figure 1); and second, it inhibits acceptance by educators who are apprehensive about teaching methods that may please students but fail to achieve publicly desired instructional goals.

This neglect of assessment has rational roots. Proper assessments are time consuming, expertise is rare, and standard assessment methods are often unsuitable to evaluate the kind of methods, systems and outcomes most important for self-directed learning. Even instructional approaches that are highly successful may fare poorly when measured by traditional yardsticks; students may learn much that is worthwhile but not measured by standard tests.

Neglecting assessment is, however, the wrong response to these issues. What is needed are alternative assessment methods that are as objective, scientific, and reliable as well-established ones, and that have the kind of face validity necessary to gain public acceptance, but are better aligned with the goals and objectives of self-directed learning.

An essential objective of self-directed learning is not only to become skillful in some cognitive task, but also to be able and motivated to use this skill in new ways. Formulating and evaluating questions and problems, as well as solutions and conclusions, and proposing and criticizing explanations, arguments, and examples is crucial to the meaningful participation in the activities of our society. Frederiksen and Collins [Frederiksen & Collins, 1989] describe some concrete ways to achieve these goals. They argue for a change from paper-and-pencil tests to assessment procedures that involve the full task environment—what actually happens in natural settings—in classrooms, workplace, or community. The learner’s performance in the task of interest should be the focus of assessment—not some artificial demand performance, but preferably long-term accomplishment in the learning task. Thus, assessment should not be concerned solely with underlying abilities, but with what learners actually do, and not with indicators of the behavior of interest, but with the behavior itself. As a consequence, assessment can become transparent: the more learners know what is expected from them, the more they are likely to give to the learning process. Moreover, assessments do not need to signal the end of learning, as summative assessments often do. Rather, assessments may be dynamic learning experiences that provide information of how one learns based on what one now knows (see Figure 1).

Assessing our own efforts to teach classes and create innovative learning environments at our university has made us aware of how major mismatches can arise in self-directed learning environments. Figure 11 (showing a a modified version of a table which appeared in: Grow, Gerald O. “Teaching Learners to be Self-Directed”; http://www.famu.edu/sjmga/ggrow) illustrates different classes of teachers and students.

Teacher	Student	Example
authority ("sage on the stage")	dependent, passive	lecture without questions, drill
motivator and facilitator	interested	lecture with questions, guided discussion
delegator	involved	group projects, seminar
coach/critic ("guide on the side")	self-directed, discovery-oriented	self-directed study group, apprenticeship, dissertation

Figure 11: Different Classes of Teachers and Students

Major mismatches can occur when (1) dependent, passive learner are confronted with non-directive teachers, and when (2) self-directed, discovery-oriented active learners are taught by directive, authorian teachers. We have *experienced* these mismatches in our courses posing interesting challenges and opportunities for creating self-directed learning environments in our educational institutions.

7. Interesting Developments and Examples for Self-Directed Learning

7.1 USA

"In Europe everything matters and nothing goes,
in America nothing matters and everything goes"

A. Federal Government

· **Initiatives at the National Science Foundation.** The National Science Foundation has focused many of its programs over the last few years on research themes of direct relevance to the themes of lifelong and self-directed learning. To name just a few recent examples (for details see http://www.nsf.gov/):

1. setting a computer science research agenda for educational technology; see also: <http://www.cc.gatech.edu/gvu/edtech/nsfws/>

2. creating a new program in *Learning and Intelligent Systems (LIS)* <http://www.ora.ucr.edu/announ65.htm>; the program is described briefly as follows: The LIS initiative seeks to stimulate interdisciplinary research that will unify experimentally and theoretically derived concepts related to learning and intelligent systems, and that will promote the use and development of information technologies in learning across a wide variety of fields. The long-range goal of this initiative is very broad and has the potential to make significant contributions toward innovative applications. To pursue this goal in a realistic and sustainable fashion, the initiative focuses on fundamental scientific and technological research undertaken in the rigorous and disciplined manner characteristic of NSF-supported endeavors. The initiative ultimately should have a major impact on enhancing and supporting human intellectual and creative potential. Consequently, development of new scientific knowledge on learning and intelligent systems and its creative application to education and to learning technologies are an integral part of this solicitation.

3. creating a new program *in Knowledge and Distributed Intelligence (KDI)* <http://www.scd.ucar.edu/info/KDI/KDIprospectus.html>; the program is described briefly as follows: Modern technologies and practices are revolutionizing the way we gather and handle information. There is great potential for both science and society to build upon the fruits of this revolution, to magnify our ability to understand and manage ever-larger and more complex systems such as those in natural, social, material, financial, and manufacturing spheres. The vision of the Knowledge and Distributed Intelligence (KDI) initiative is to achieve, across the scientific community, the next generation of human capability to: (1) Generate or gather, and represent more complex and cross-disciplinary scientific data and information, from new sources and at enormously larger scales; (2) Tranform this information into knowledge by combining, classifying, and analying it in new ways; (3) Collaborate in groups and organizations, sharing this knowledge and working together interactively across space, time, disciplines, and scientific cultures to multiply results.

4. exploring the topic of *human-centered system design* <http://www.ifp.uiuc.edu/nsfhcs/>

- **President's Committee of Advisors on Science and Technology, Panel on Educational Technology: "Report to the President on the Use of Technology to Strengthen K-12 Education in the United States, March 1997.**

  <http://www.whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/k-12ed.html>

Executive Summary (abbreviated according to its relevance to SDL and LLL) In an era of increasing international economic competition, the quality of America's elementary and secondary schools could determine whether our children hold highly compensated, high-skill jobs that add significant value within the integrated global economy of the twenty-first century or compete with workers in developing countries for the provision of commodity products and low-value-added services at wage rates comparable to those received by third world laborers. Moreover, it is widely believed that workers in the next century will require not just a larger set of facts or a larger repertoire of specific skills, but the capacity to readily acquire new knowledge, to solve new problems, and to employ creativity and critical thinking in the design of new approaches to existing problems.

While a number of different approaches have been suggested for the improvement of K-12 education in the United States, one common element of many such plans has been the more extensive and more effective utilization of computer, networking, and other technologies in support of a broad program of systemic and curricular reform. During a period in which technology has fundamentally transformed America's offices, factories, and retail establishments, however, its impact within our nation's classrooms has generally been quite modest.

A substantial number of relatively specific recommendations related to various aspects of the use of technology within America's elementary and secondary schools are offered at various points within the body of this report. The list that appears below summarizes those high-level strategic recommendations that the Panel believes to be most important:

1. Focus on learning with technology, not about technology.
2. Emphasize content and pedagogy, and not just hardware.
3. Give special attention to professional development.
4. Engage in realistic budgeting.
5. Ensure equitable, universal access.
6. Initiate a major program of experimental research.

It should be noted that the Panel strongly supports the programs encompassed by the President's Educational Technology Initiative, which aim to provide our nation's schools with the modern computer hardware, local- and wide-area network connectivity, high quality educational content, and appropriate teacher preparation that will be necessary if information technologies are to be effectively utilized to enhance learning. In the area of research and evaluation, however, the Panel believes that much remains to be done. While a scientific research program of the sort envisioned by the Panel will require substantial funding on a sustained basis, such a program could well prove critical to the economic security of future generations of Americans, and should thus be assigned a high priority in spite of current budgetary pressures.

- **A paper entitled "Leveraging Cyberspace" by Thomas A. Kalil, Senior Director, National Economic Council, The White House which appeared in IEEE Communications Magazine, July 1996, pp. 82-86**

<http://nii.nist.gov/cyber/cyber.html>

Abstract. People with shared interests are using the Internet to solve problems, accomplish tasks, and create resources that would be well beyond the reach of any one person or organization. The Internet is being used to create virtual libraries, factor large numbers, organize massive volunteer efforts, and filter information in a collaborative fashion. The ability to leverage the efforts of large numbers of networked users has important economic, social, and political consequences. This phenomenon is important to policy makers because it can potentially be used to leverage scarce taxpayer dollars and promote applications of the information infrastructure.

- **Working Document The Seven Priorities of the U.S. Department of Education (July 1997) —Priority Six: Every Classroom will be Connected to the Internet by the Year 2000 and All Students will be Technologically Literate**

<http://www.ed.gov/updates/7priorities/part8.html>

Abstract. As the nation moves toward the next century, a student's ability to learn to higher standards will be inseparable from his or her ability to access and understand technology. The livelihood of all Americans will depend on their ability to harness and use knowledge to adapt to the available jobs, which, in turn, will depend in large part on one's technological literacy. As early as the year 2000, approximately six out of every ten jobs in America will require computer skills currently possessed by only 22 percent of the labor force.(18) And yet today, although 65 percent of schools are wired to the Internet, only fourteen percent of classrooms are connected and only one of every five teachers now use it. (19) Additionally, the availability of quality software to help teach to rigorous standards is limited.

B. Private Foundations — William K. Kellogg Foundation

< http://www.wkkf.org/>

The W.K. Kellogg Foundation is a nonprofit organization whose mission is "to help people help themselves through the practical application of knowledge and resources to improve their quality of life and that of future generations." Its founder, W.K. Kellogg, the cereal industry pioneer, established the Foundation in 1930. Since its beginning, the Foundation has continuously focused on building the capacity of individuals, communities, and institutions to solve their own problems.

C. Scientific Meetings and Scientific Journals

Over the last decade, a number of scientific **meetings** emerged and got institutionalized. Some interesting examples for self-directed and lifelong learning and its support with computational media are:

1. Computer-Supported Collaborative Learning (CSCL),
2. International Conference of the Learning Sciences (ICLS),
3. Artificial Intelligence and Education (AI&ED),
4. Intelligent Tutoring Systems (ITS),
5. Design of Interactive Systems (DIS), and
6. User Modeling (UM).

Some of the most relevant **journals** are:

1. Journal of the Learning Sciences (Lawrence Erlbaum),
2. Human-Computer Interaction (Lawrence Erlbaum),
3. Cognitive Science (Ablex), and
4. User Modeling and User-Adapted Interaction (Kluwer).

D. Major Studies and Reports

- **"Untangling the Web: Applications of the Internet and Other Information Technologies to Higher Education", by David McArthur and Matthew Lewis, October 31, 1997**

<http://www.rand.org/publications/DRU/DRU1401/>

Abbreviated Summary — Until very recently, discussions of the crisis in U.S. education centered exclusively on public schools in the United States; higher education has been viewed as almost trouble-free -- the best in the world. Today, however, several problems loom: Many states budgets for higher education are falling, and some are poised for truly terrifying reductions even as student populations are increasing and becoming more diverse (in age as well as ethnic composition). At the same time, even as resources are shrinking, industries and consumers are demanding more of colleges. Further, a broad shift from manual workers to "knowledge workers" means that students will require more education: High school diplomas no longer guarantee good job prospects. And many predict that job skills will need updating every few years; if so, "lifelong learners" will continue to demand education and retraining throughout their careers. All these changes are straining institutions of higher education to the breaking point.

In this report, we look broadly at the prospects of meeting some of these challenges with a new generation of information technologies. We review and analyze, in particular, the emerging global information infrastructure -- the first pieces of which we now see in the Internet and World Wide Web -- and the multiple roles they can play in higher education:

1. to improve learning and teaching
2. to improve the creation of instruction and learning materials
3. to create educational communities to compete with new providers
4. to address policy and planning issues.

E. Critical Voices

The value of self-directed and lifelong learning and the attempts of creating innovative innovative new media are notuniversally shared by decision makers, researchers, scientists, educators, parents, and students. While it goes beyond the scope of this study to carefully analyze the detailed arguments, the following books and articles are worthwhile to be studied carefully:

- **E. D. Hirsch**: "The Schools We Need And Why We Don't Have Them" [E.D. Hirsch, 1996] — Hirsch is a well-known figure in the USA in favor of acquiring "cultural literacy" (acquiring a set of facts which every American should know) and is one of the major critics of progressive education. Self-directed learning, lifelong learning, discovery learning, etc. in his view are all concepts and directions which have been misleading and counterproductive to educate young people.

- **Neil Postman**: "The End of Education" [Postman, 1995] — this book is not really, as the title suggests, about the termination of education; rather, it's about what should be the goal of the educational enterprise (the "end", as opposed to the "means"). Postman writes about the underlying "gods" (in the sense of "myths" or "guiding narratives") that have thus far failed to serve education.
- **Todd Oppenheimer**: "The Computer Delusion" , in the Atlantic Monthly, July 1997: Oppenheimer argues that there is no good evidence that most uses of computers significantly improve teaching and learning, yet school districts are cutting programs — music, art, physical education — that enrich children's lives to make room for this dubious nostrum, and the Clinton Administration has embraced the goal of "computers in every classroom" with credulous and costly enthusiasm (http://www.theatlantic.com/issues/97jul/computer.htm).

F. Future Role of the University

- **John Seely Brown and Paul Duguid: "Universities in the Digital Age"**

http://www.parc.xerox.com/ops/members/brown/papers/university.html

Abstract. The university's value, we claim, lies in the complex relationship it creates between knowledge, communities, and credentials. Changes contemplated in either the institutional structure or technological infrastructure of the university should recognize this relationship. In particular, any change should seek to improve the ability of students to work directly with knowledge-creating communities. We offer a couple of examples of currently successful Internet-supported teaching that suggest how technology can do this. Then we explore some hypothetical institutional arrangements that might enable the university to take the fullest advantage of these emerging technological possibilities.

- **Eli M. Noam: "Electronics and the Dim Future of the University" (source: SCIENCE, VOL. 270, pp. 247-249, 10/13/95)**

Abstract. By now, everybody knows about it--about the tremendous advances in computer networks as tools of inquiry; about the free communication links among researchers around the world; about the loss of stifling organizational hierarchy and coercive governmental controls; and about the ethic of sharing information instead of commercializing it. Technology, it seems, has created a new set of tools for academic endeavors, strengthening and enriching the existing research environment.

Parts of this exciting scenario are indeed coming true. Yet to conclude that the global academic village is all gain and no pain (beyond perhaps the need to protect against a few immature but creative youngsters) would be naive. True, communications technology will link the information resources of the globe. But as one connects in new ways, one also disconnects the old ways. Thus, while new communications technologies are likely to strengthen research, they will also weaken the traditional major institutions of learning, the universities. Instead of prospering with the new tools, many of the traditional functions of universities will be superseded, their financial base eroded, their technology replaced, and their role in intellectual inquiry reduced. This is not a cheerful scenario for higher education.

G. Research Institutes Working on Self-Directed Learning

There is a substantial number of research institutes, which explore questions, conceptual frameworks, new computational environments, practices and assessment as discussed in this report. A brief list (including their own description) is documented in Appendix 2).

7.2 Europe

While this report focuses on developments in the USA, I want to inlcude a few European efforts (e.g., Esprit Programs) to indicate that there is substantial interest in Europe in the themes of learning, lifelong learning, self-directed learning and its support with new media as well. While one can argue that the different communities (e.g., education, adult education, computer science, cognitive science, etc.) collaborate insufficiently in the USA, I believe that they are even further apart in Europe.

- **Information Access and Interfaces**

<http://www.cordis.lu/esprit/src/interfac.htm>

Abstract. The information society is making vast information resources available to anyone, at any time, from anywhere in the world. Business competitiveness increasingly depends on timely access to the right information and on the capability to act upon it effectively and efficiently, while citizens will turn more and more to new electronic information and services for work, entertainment, and managing of everyday life.

The objective of Information Access and Interfaces is the development and deployment of applications, systems, tools, and appliances that contribute towards the intelligent information handling for non-IT specialists, focusing on three major challenges: mastering information overload; "naturally" interactive information interfaces; and novel tools or environments for "creating value".

- **IT for Learning and Training in Industry (Esprit Programme)**

<http://www.cordis.lu/esprit/src/learners.htm>

Abstract. To develop and experiment with IT-based tools, processes and infrastructural means that support and enhance the learning capability and the learning effectiveness of individuals and organisations.

- **ESPRIT Call on Experimental School Environments (ESE)**

http://nakskov.mip.ou.dk/schools/

Abstract. Education as child’s play:— Esprit explores new ways of learning for children. The programme seeks major advances in both education and technology. It is geared towards the development of key skills such as creative problem solving, working in teams and above all learning to learn, making learning fun and engaging experience through technological innovation.

- **Green Paper by the European Commision entitled “Living And Working in the Information Society: People First”**

<http://www.ispo.cec.be/infosoc/legreg/docs/people1st.html>

Abstract. What Europe needs is a substantial overhaul of education and training that can match the ICT revolution and keep pace with the continued ICT development during the years to come. We need a new interplay between work and training, instead of the old interplay between work and non-work, a new interplay which gives the individual the opportunity to develop skills and competencies and to grow in tune with the permanent revolution of skills that accompanies ICTs. In the long-term the underlying need is for Europe to develop a new architecture of life-long education and training, involving all parts of education and training systems, including schools and designed and delivered in more appropriate ways, with particular regard to gender, but also by engaging more effectively older people and those with disabilities. This effort is now being initiated by the 1996 European Year of Lifelong Learning and the White Paper on Teaching and Learning. But the urgent need is to arrest the growing skill obsolescence of the adult working population through a pro-active approach to industrial adaptation and change. Speed and foresight are of the essence, because all the evidence points to a vicious downward spiral of job destruction, long-term unemployment and skill obsolescence which is harder to correct the longer it goes on. .

Areas are of great importance in enhancing employability: “from *teaching to learning*;” — since learning retention is much higher (80%) by "doing" rather than reading or hearing (5-10%) the potential for self learning using ICTs is immense, and if shaped correctly, could be a key tool for closing the knowledge gap itself. The basic principles of education and training have to be based more on the notion of learning capacities, rather than formal education and training.

8. Recommendations

"Der Worte sind genug gewechselt, lasst mich auch endlich Taten sehn!"*Goethe "Faust"*

"Wer erneuern will, hat alle die zum Feind, denen es unter den alten Bedingungen gut ergangen ist" —Machiavelli

The following recommendations are based on the themes and issues raised and discussed in this report. They provide a conceptual framework (1) to further explore the strengths and weaknesses of self-directed and lifelong learning, and (2) to evaluate research proposals and actions exploring themes and approaches of self-directed and lifelong learning.

Theme: Understand The Magnitude Of The Change

Claim: Our current thinking does not address the potential magnitude of the change. One can argue that we have arrived at a point where the change is of a similar magnitude to the time when our society moved from an oral to a literary society or when the printing press eliminated the scribes and gave everyone the opportunity to become literate.

Recommendation: Understand the long-term societal impacts of self-directed and lifelong learning. Self-directed and lifelong learning need to be more than a label or the adoption of surface practices. Reinvent our educational institutions and our work environments to make learning a part of life.

Theme: Distributed Cognition

Claim: The individual human mind is limited — therefore in real life (i.e., outside of schools) people rely heavily on information and knowledge distributed among groups of people and various artifacts.

Recommendation: Deemphasize rote learning and closed-book exams. Support social environments enriched by embedded computational media which emphasize collaborative learning and communication skills.

Theme: Reality is not user friendly

Claim: In lifelong and self-directed learning, people encounter the need for learning coming from a large variety of backgrounds and being engaged in a great variety of different tasks.

Recommendation: Provide multiple educational forms and opportunities rather than try to design the "one best" educational and computational environment. Teacher-driven approaches (such as intelligent tutoring systems) will be inadequate to support people in self-directed learning.

Theme: Changing Roles

Claim: In the past, the role of a teacher or a learner was associated with in person. In the learning environments of the future (characterized by a "symmetry of ignorance" among the participating stakeholders) these roles are changing dynamically dependent on the issues and questions under investigation. Questions arising from self-directed learning activities (as opposed to presentations by the teacher) will indicate the limitations of the teachers' knowledge.

Recommendation: Change the role of the teacher from an oracle to a coach, mentor, and facilitator and support peer-to-peer learning. Teachers need to be comfortable interacting with learners in situations in which they do not know everything.

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Theme: Beyond a Divided Lifetime — Beyond the "Big Switch" Approach

Claim: Educational institutions need to prepare learners and workers for a world that relies on interdependent, distributed, non-hierarchical information flow and rapidly shifting authority based on complementary knowledge. Lifelong learning is more than "adult education"; it covers and unifies all phases: intuitive learner (home), scholastic learner (school and university), and skilled domain worker (workplace). It is a misleading assumption that humans at a certain age will be able to throw the "big switch" and become self-directed learners after they have not experienced and practiced this during their the first 30 or forty years of their lives.

Recommendation: Close the gap between school and workplace learning by allowing learners to engage in activities requiring collaboration, creativity, problem framing, and distributed cognition. Integrate learning into working and playing instead of conceptualizing it as a separate activity.

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Theme: New Interdisciplinary, Cross-Cultural Collaborations

Claim: Realistic problems are framed and solved by groups , communities and organizations rather than individuals. The participants come from different "cultures" (different profession, different countries, different objectives) and must have the willingness, the experience, the environments and the tools to abe able to learn from each other.

Recommendation: The role of a community of learners with different backgrounds needs to be explored and explicitly incorporated into our conceptual frameworks and computational media. Develop environments supporting mutual learning and mutual understanding.

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Theme: Economics and the Quality of Education

Claim: Education needs to be cost-effective. While new media offer the possibility to reduce the cost of education, an equally important goal is to improve the quality of education ("If you think education is expensive, try ignorance!").

Recommendation: Explore the scalability of educationally desirable innovations (for example, the Nobel prize winner as a private coach does not scale). Design and develop computational media to support learners in their own doing. Create new role distributions between humans teachers and computational media. While there is no evidence that all the tasks of a teacher can be 'handed over' to a computer, new media allow us to rethink the role of the teacher.

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Theme: Avoid To Reinvent The Wheel

Claim: Self-directed learning should not underestimate the knowledge of the past. Let Learners stand on the shoulders of the giants who proceeded them!

Recommendation: Self-directed learning (as any other approach towards learning and teaching) should complement other approaches. Instructionist approaches are suited to make the knowledge of the past available under the guidance of an experienced teacher.

Theme: Support Collaborative Knowledge Construction

Claim: While we face too much information in the abstract, in most specific problem situations we do not have enough knowledge.

Recommendation: Learning can not be restricted to finding knowledge which is "out there". If nobody in a group knows the answer, we have to create new knowledge. Create environments which stimulate innovation and creativity by exploiting breakdowns, symmetry of ignorance, experimentation, and external objects serving as objects-to-think-with and objects-to-talk-about.

Theme: "Basic" Skills — Core Knowledge

Claim: A lifelong learner cannot learn any arbitrary skill on demand—prerequisites normally limit what a person can and cannot learn. This raises the important question: what "basic skills" are required in a world in which occupational knowledge and skills become obsolete in years rather than decades?

Recommendation: The "old" basic skills (such as reading, writing, and arithmetic) once acquired, were relevant for the rest of a human life; modern "basic skills" (tied to rapidly changing technologies and media) change over time. Education cannot be reduced to mere skill acquisition and information processing, but needs to prepare students to become self-directed and lifelong learners by creating passion and deep understanding about their existence as human beings in the future knowledge society.

Theme: New Assessment Strategies

Claim: Self-directed learning makes assessment strategies infeasible in which everyone is measured with the same yardstick and in which human capabilities are reduced to a number. New approaches should not avoid the assessment challenge —it is legitimate to ask for evidence that the "new" approaches are working.

Recommendation: Assessment strategies developed for instructionist learning are not suited to assess for self-directed learning. The development of new assessment strategies addressing the needs of self-directed learning is an important research problem.

Theme: Take Motivation Seriously

Claim: If we want people to be lifelong learners, we must make sure they enjoy it. *Motivation* is central to learning.

Recommendation: The beginnings of a motivational theory urgently need to be developed further. One of the benefits of integrating working and learning is the potential increase in motivation. Motivation to learn new things is critically influenced by optimal flow, a continual feeling of challenge, the right tools for the job, and a focus on the task.

Theme: Develop Innovative Media in Support of Lifelong, Self-Directed Learning

Claim: Non-computational media (such as books, films, etc.) in principle cannot analyze and critique the work of learners and contextualize new information, advice and help to their work.

Recommendation: The interpretive power of computational media is needed to support people in their own doing. To make self-directed learning economically feasible, new kinds of media are needed which are able to analyze and critique a students work. Develop requirements and create prototypes of computational environments in support of self-directed learning; examples of such requirements are: they must be user-directed and simultaneously supportive; provide information in context; exploit breakdowns as opportunities for learning, allow end-user modification and programmability; support a range of expertise, and promote collaboration.

Theme: Educate New Kinds Of Professionals

Claim: Education must prepare humans for a world where learning is an integral part of their lives. Industrial-age models of education are inadequate to prepare students to compete in the knowledge-based workplace.

Recommendation: Create educational settings for young researchers and students (at a formative stage in their careers) in which they can learn how to learn, are able to engage in personally meaningful activities, exploit the power of media, and collaborate with others in interdisciplinary and cross-cultural settings.

Theme: Beyond Technology: Change Mindsets and Organizations

Claim: There is no evidence from the past that technology by itself has changed education, learning and teaching in any fundamental way, especially technologies used in the “gift wrapping” mode.

Recommendation: Develop new mindsets and attitudes among (1) individuals (e.g.: learners, teachers, researchers, policy makers, etc.) and (2) organizations (e.g.:, nurturing a collaborative work environment, being willing to undergo culture changes).

9. Conclusions

The major objective of this report was to provide an overview and a critical assessment of experiences (specifically in the USA) in the use of new media in support of self-directed and lifelong learning. Unfortunately (as it is probably the case with all important questions and challenges) there are no simple answers and no simple facts which would allow to enumerate briefly failures and successes. To acknowledge the complexity of the central question implies that we rethink, reinvent and redesign the way how we think, work, learn and collaborate in the future. We have to understand the co-evolutionary processes between fundamental human activities and their relationship and interdependencies with new media. We need progress and a deeper understanding of new theories, innvovative systems, practices, and assessment (as illustrated in Figure 1). We need new intellectual spaces, new physical spaces, new organizational forms, and new reward structures to make self-directed and lifelong learning an important part of human life. Last but not least: we need individuals, groups, and organizations to personally engage and experience these new forms — risk takers who uses their creativity and imagination to explore alternative ways of learning.

Appendix: Research Institutes Working on Self-Directed Learning

Remark: In this appendix I have selected a few research institutes and other innovative organizations which engage in some interesting aspects of self-directed and lifelong learning. I used text from their Web pages to provide a brief description for the reader. For details, the Web pages at the given URLs should be consulted.

Computer Supported Intentional Learning Environments (CSILE), University of Toronto

http://csile.oise.utoronto.ca/

The Research Base. After more than two decades, cognitive science (the study of how people think, learn and remember) has reached a point where it generates approaches to teaching and learning that are both practical and effective. One basic finding confirmed in countless studies is that learning results from thinking. When students actively try to make sense of what they are learning they understand it better, they remember it better, and they can even use it to solve new problems. And so, whatever the subject, research tells us that the goal is to encourage students to reach a genuine understanding which goes well beyond rote memorization. CSILE (Computer Supported Intentional Learning Environment) is a program designed to help students achieve extraordinary learning by providing supports for thinking and understanding.

What It Is. CSILE is the first network system to provide across-the-curriculum support for collaborative learning and inquiry. At the center of the CSILE software is a communal database, created by students and their teachers. Students can enter text and graphic notes into the database on any topic their teacher has created. All students on the network can read the notes and students may build on or comment on each others' ideas. Authors are notified when comments have been made or when changes in the database have occurred. Various note formats and supports are designed to enhance the potential of the communal database for collaborative knowledge-building.

More Than Software. Unlike most educational technology, CSILE was not created in the laboratory and then tried in the classroom. From the beginning (in 1986) CSILE was the result of cognitive scientists, computer scientists, teachers, and students working together at school sites to produce a new model of education. The real distinctiveness of CSILE lies in a harmonious integration of research-based software and teaching methods that have grown up together, each influencing the other and resulting in a powerful combination.

Uses. CSILE has been used in regular educational programs ranging from primary grades to graduate school. The typical school installation consists of 8 computers in each classroom networked to a common file server. CSILE is currently running in over 50 classrooms and several cultural institutions in Canada, the U.S., Europe, Australia, and Japan. It is an integral part of the Schools for Thought program in the U.S. and also one of four beacon technologies being developed for the TeleLearning Network of Centers of Excellence. CSILE has the potential of becoming the software environment within which technology-based education and training will take place in the future.

Knowledge Forum — a second generation CSILE product. With Knowledge Forum, classrooms are similar to knowledge-based organizations – exciting places where success depends on the careful cultivation and constant use of the organization's knowledge resources. In these organizations, maximizing the production of knowledge and the advances that are made depends on an organizational design that defines each person as a contributor.

With Knowledge Forum, students become contributors of this sort – they pose questions, define their own learning goals, acquire and build a knowledge base, and collaborate with their peers.

The on-going practice of these advanced operations, combined with teacher support and coaching, helps students to acquire the learning strategies that characterize 'expert' learners.

Knowledge Forum includes tools for: collaborating building networks of ideas constructing, storing, and retrieving notes identifying gaps and advances in knowledge viewing the knowledge base from different and interesting perspectives

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Knowledge Integration Environment (KIE) Project, UC Berkeley

http://www.kie.berkeley.edu/KIE.html

The KIE project is dedicated to advancing our understanding of students' learning in science and the role of technology in education. Educational research efforts currently underway include:

1. Design and Use of On-line Scaffolding and Guidance
2. Student Search Strategies on the Internet
3. Individual and Collaborative Sense-Making of Scientific Evidence
4. Socially-Relevant Representations for On-Line Discussion Tools

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Institute for Research on Learning (IRL), Palo Alto

http://www.irl.org/

The Institute for Research on Learning (IRL) was founded in 1987 as a response to the escalating learning crisis in the United States. IRL's mandate, to "rethink learning," addresses the root cause of this crisis--a limited understanding of successful everyday learning. Our research-in-action approach takes us beyond thinking to doing--to a set of tools, methods and technologies that enable us to bring about effective change.

Our ultimate aim is the creation of environments in which people can realize their full potential for learning. We achieve this goal through a set of "core capabilities" that are based on the knowledge and skills of our multidisciplinary research team.

Bringing the perspectives of diverse fields together to focus on problems of learning has helped create the kind of dynamic intellectual atmosphere in which breakthrough thinking is possible. What has emerged is a body of theory of learning, informed not only by cognitive science but also through contributions from the fields of anthropology, education, computer science, artificial intelligence, psychology, sociology, linguistics and others.

In contrast to traditional models which have emphasized abstract knowledge and the purely cognitive aspects of learning, we view learning as a fundamentally social activity that is interwoven into the practices of communities of people.

This idea is at the center of the deep, theoretical framework through which we view the world--the "eyeglasses" that enable us to see learning and to develop the approaches, tools, methods and technology that support learning.

Institute for the Learning Sciences (ILS), Northwestern University.

http://www.ils.nwu.edu/index.html

Welcome to the Institute for the Learning Sciences (ILS) at Northwestern University. Established in 1989 with the founding sponsorship of Andersen Consulting, ILS is an interdisciplinary research and development center dedicated to developing and transferring innovative educational technology from the laboratory to practical applications in businesses, schools, government agencies, and the community.

Using theories and models from the fields of artificial intelligence, computer science, cognitive science, and education, we build educational software for use in multimedia computers, which provide individualized instruction to learners. ILS draws together faculty and students from the fields of computer science, psychology, cognitive science, and education. Located in the Northwestern University/Evanston Research Park,

ILS's mission is to dramatically improve human learning through effective education and training. To accomplish this, we build educational software that enables children and adults to develop relevant, real-world skills as they learn by doing; and create software tools--rich in educational theory and content--that make our software applications easy to use and less expensive to produce, and that will eventually enable teachers and corporate trainers, among others, to build customized educational software.

The Epistemology and Learning Group, MIT Media Lab, Cambridge

http://el.www.media.mit.edu/groups/el/

The Epistemology and Learning Group at the MIT Media Lab explores how new technologies can enable new ways of thinking, learning, and designing. The group creates new "tools to think with" and explores how these tools can help bring about change in real-world settings, such as schools, museums, and under-served communities.

Learning through Design. Our research is guided by the constructionist theory of learning. Constructionism asserts that knowledge is not simply transmitted from teacher to student, but is actively constructed by the mind of the learner. Moreover, constructionism suggests that learners are particularly likely to create new ideas when they are actively engaged in making external artifacts that they can reflect upon and share with others. In our research, we develop new technological tools to support children as designers -- for example, helping them create their own video games, robots, and simulations. The projects also probe how and what children learn through the process of designing and making.

Learning in Communities. Much of our research focuses on the social nature of thinking, recognizing that how people think and learn is deeply influenced by the communities and cultures with which they interact. Our research projects explore how new technologies and new media can change relationships within existing communities (such as urban neighborhoods), while also encouraging the development of new types of "virtual" communities over computer networks. The projects also examine the development of communities among teachers, and the development of "communities of learning" within individual classrooms.

Learning about Systems. Ideas about systems are important in a wide range of sciences, engineering, and social sciences. New computational media are significantly altering how researchers study and think about systems, while also making systems ideas more accessible to younger students. Our research projects probe how students think about systems concepts (such feedback and self-organization), and demonstrate new ways for students to learn about such concepts. Among the projects are several "construction kits" that allow children to create (and experiment with) animal behaviors, either on the computer screen or with LEGO "creatures."

The EduTech Institute, Georgia Institute of Technology, Atlanta

http://www.cc.gatech.edu/cogsci/edutech/

The EduTech Vision. In January, 1993, Georgia Tech was awarded funds for applying technology to enhancing and facilitating technological education. Emphasis was to be on two technologies: multimedia and the cognition of learning. EduTech will develop and implement innovative and effective applications of technology to education. Its special emphasis will be on applying what we know about how people learn to the development of effective learning environments. The influence of these cognitive principles will be seen in the development of curricula; innovative pedagogical principles and practices; and software, multimedia, and networking tools. EduTech will concentrate on the education of Georgia Tech students, taking seriously also the dissemination of its results to local elementary and secondary schools, industrial training programs, and other post-secondary colleges and universities. EduTech's efforts will include both research into relevant educational issues and implementation of new educational programs and technology. Rationale:

Rationale. As the workplace changes, we are finding that our workers need to know more than just the facts and technical skills we have traditionally been teaching them. With the half-life of technical knowledge at only five years, workers need the skills to continue to learn on the job. In addition, as projects become more complicated, it is becoming more and more important for our workers to have collaborative skills -- to be able to work together with others who have different expertise and to be able to appreciate that other expertise and synthesize it with their own.

Decision-making in the workplace is often done under conditions of noisy, ambiguous or incomplete data. Choosing between alternatives requires projecting into the future, with all the attendant uncertainty that holds. Yet much of the education students receive introduces them to deriving solutions in formulaic ways, neglecting to show them the kinds of complexities that arise when solving problems in the real world.

If our students are to contribute to their greatest potential in the workplace, then in addition to learning facts, they need to learn the thinking skills that will allow them to tackle new projects well even though they have large gaps in what they know. They need to be able to transfer thinking skills, and not just facts, to new situations. They need skills for dealing with uncertainty and incompleteness. They need to be able to articulate their thoughts to others working on their projects and to know how to work well in groups. And they need the skills to learn both the new knowledge they need to work in a new area and the models and strategies for dealing with problems in those areas.

There is considerable agreement among those who have thought about educating for the future workplace that we need to augment education in facts with education in reflection, helping students to understand the thought processes they are using to solve problems, and that we need to involve our students in real-world kinds of experiences while in school, allowing them to learn collaborative and synthesis skills that might otherwise go unlearned.

In addition, there is growing recognition that our students don't know enough about science and technology to participate knowledgeably in many decisions they will face as citizens -- they are not able to evaluate science and technology issues as they arise and take them into account in their voting behavior. This bodes poorly for an economy that prides itself on its technology and that needs technological excellence to grow. Studies show that while traditional education programs address the needs of those who would learn whatever the environment, many more students are scared away by the ways in which science and technology are presented. Some of those students would be excellent for our technological workforce. Others simply aren't learning what is needed to be responsible members of the community.

The traditional "lecture and absorb" approach in which facts are presented for students to absorb makes learning difficult for many students, who then decide that science and engineering are not for them. This is not surprising, as recent studies about the cognition of learning tell us that a combination of abstract and concrete are needed for good learning, that question asking by learners before presentation of new material allows easier integration of that material with what they already know (i.e., if they are ready to learn because they see the need to learn some new piece of knowledge, then learning is facilitated), and that learning is far more effective when learners can construct the new knowledge they are to learn first-hand than when it is presented for them to absorb.

TAPPED IN: An On-line Teacher Professional Development Community Workplace — Stanford Research Institute, Palo Alto

http://www.tappedin.sri.com

A shared need for more meaningful on-line interactivity than can be supported by Web pages and listservs has motivated several K-12 TPD organizations to join SRI in developing a new vision of on-line professional development based on the premise that learning to understand and implement reform-based practices occurs most effectively (a) within an environment that supports rich collaborative discourse and (b) surrounded by a well-established and diverse community of practice engaged in the work of education reform. We envision a place where teachers with diverse interests, skills, and backgrounds can meet and learn from one another anytime; where teachers can be exposed to not one but many education reform concepts and approaches; where teachers can find high-quality resources in minutes rather than hours.

As a proof-of-concept that more can be done now to support this on-line TPD vision, SRI developed the Teacher Professional Development Institute (TAPPED IN), a platform-independent, Web-aware multi-user virtual environment (MUVE). TAPPED IN integrates synchronous and asynchronous communication, document storage and sharing, and interaction with virtual objects in a venue patterned after a real-world conference center. Teachers can log into TAPPED IN to share Web resources, hold meetings and workshops, engage in mentoring, and conduct collaborative inquiries with the aid of familiar discourse-support artifacts such as whiteboards, file cabinets, and bulletin boards.

Integrated Teaching and Learning Laboratory (ITLL), College of Engineering, CU Boulder

http://itll.colorado.edu/

The Integrated Teaching and Learning Laboratory (ITLL) is based on the vision “to pioneer a multidisciplinary learning environment that integrates engineering theory with practice and promotes creative, team-oriented problem-solving skills.” A special effort was made to instantiate this vision as a new approach to learning and construct a new building driven by and supporting this educational approach. The building appeals to students’ curiosity and sprit of inquiry, features formal and informal learning spaces, “brainstorming rooms”, interdisciplinary experimental learning plazas, state-of-the-art technology, and unique educational tools.

Center for LifeLong Learning and Design (L3D)

http://www.cs.colorado.edu/~l3d/

Success Stories — Collaborations and Application and Assessment of our Approach. Claiming that we have ideas, frameworks, and computational environments to "make learning a part of life", we believe that in order to remain credible in the long run, self-application within our own university is critical ("we have to put our money where our mouth is"). Over the last few years we have tried to instantiate our conceptual framework as follows:

- To allow students to engage in authentic, self-directed learning activities, we have designed new courses for students emphasizing self-directed learning, learning on demand, collaborative learning, and exploring the utility of the WWW as a teaching and learning tool.. Using our experiences in these courses, we have analyzed the far-ranging changes for teaching based on such an approach (e.g., the incompatibility of a micro-managed curriculum and engagement in self-directed learning activities) and we have presented the course as models to other faculty members at our university.

- To increase vertical integration between different learner populations, we are trying to break down the boundaries between undergraduates, graduates, post-doctoral fellows, faculty members , researchers and developers from industry, and citizens.

- In collaboration with the Boulder Valley School District, we have an ongoing research effort (supported by NSF) to understand the issues associated supporting *teachers as lifelong learners*.

- For several years, we have collaborated with NYNEX University and NYNEX Science & Technology to develop new models, new approaches, and new computational artifacts to create a learning organization (with a special focus on integration of working and learning, self-directed learning andorganizational learning).

- CU Boulder is currently in the process of creating new alliances (to overcome the gaps between the "two cultures" postulated by C.P. Snow) between departments, institutes, and centers (such as computer science, fine arts, film studies, journalism and mass communication) where historically few interactions have taken place. These academic units will be tied together in the Alliance for Technology, Learning and Society (ATLAS).
- **L3D is developing computational environments in support of self-directed learning such as**

  (1) WebQuest an interactive Quest Game. It is a construction environment that allows students to play, to build interactive simulation games, and to engage in self-directed learning using the World Wide Web as a research medium. WebQuest has been used with over 150 students at middle and high schools **(**http://www.cs.colorado.edu/~corrina/mud/).

  (2) **Mr. Roger's Sustainable Neighborhood** is a grass-roots communication tool in the form of a game which utilizes the World Wide Web and Agentsheets to aid concerned citizens and the professionals who wish to become involved in designing their community's sustainable future. Mr. Roger's Sustainable Neighborhood supports self-directed learning in the context of design and planning processes by bringing concerned citizens and professionals together to address, discuss, plan and design their community's sustainable future (http://ucsu.colorado.edu/~spencers/neighborhood/).

Amazon — An Online Bookstore

http://www.amazon.com

Amazon has created one of the most innovative websites to support their online bookstore. The website illustrates a number of interesting features and mechanisms of interest to self-directed learning. Readers can create a "book memory" in which the views of readers who contribute their view of the book are accumulated and made available to all visitors.

Disney Institute

http://www.disney.com/DisneyWorld/index.html

The Disney Institute is a whole new Disney vacation experience. A resort community with a campus-like setting, the Disney Institute offers dozens of hands-on programs and activities taught in a relaxed, social atmosphere by fun-loving instructors who are experts in their fields.

Imagine trying your hand at animation, gourmet cooking, TV production, and much more, plus enjoying our state-of-the-art Sports and Fitness Center and spa. Evenings offer live entertainment or film screenings by some of the most respected names in the business. And don't forget to save a day to visit one of the Walt Disney World Theme Parks.

Discover this vacation, where every day is different, and every day is yours to design. It's unlike anything you've ever experienced. What's a day at the Disney Institute like? The possibilities are endless, but imagine a morning where you head for a rock wall and discover the exhilaration of rock climbing. After a fantastic lunch at Seasons Dining Room, you walk to the South Studios for a clay animation workshop, where you create a clay character and bring it to life on film. Then it's on to The Spa at the Disney Institute for a massage or facial. It's already been a day like no other, and it's not over yet. After a wonderful meal at Seasons, you complete the day with an evening of world-class entertainment...maybe a screening in the Cinema or a jazz group in the Performance Center. Tomorrow? Eighteen holes in a golf program, followed by an afternoon at a Walt Disney World Theme Park.

The Disney Institute allows learners/vacationers to participate in topics such as Performing Arts & Film and Culinary Arts.

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