EXTERNAL AND SHAREABLE ARTIFACTS AS OPPORTUNITIES FOR SOCIAL CREATIVITY IN COMMUNITIES OF INTEREST

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Abstract. Complex collaborative design activities cannot be solved by individuals or by a single group. *Communities of interest* (defined by their collective concern with the resolution of a problem) bring together several *communities of practice* that represent groups of practitioners from different domains. Reaching common understanding between these communities is a major challenge for information technologies due to the communication divide that exists between their respective cultures. *Social creativity* exploits the "symmetry of ignorance" to create new artifacts and new understanding in the context of framing and solving design problems. This paper develops a conceptual framework that emphasizes the critical importance of *externalizations* (specifically boundary objects) for social creativity in communities of interest. This framework has been used in our theory-guided system development efforts such as domain-oriented design environments, the Envisionment and Discovery Collaboratory, organizational memories, and course information environments. These socio-technical environments illustrate the need, the use, and the possibilities for creating design situations that can be understood and further evolved by all stakeholders.

Keywords: collaborative design, individual creativity, social creativity, symmetry of ignorance, meta-design, boundary objects, communities of interest (CoIs), communities of practice (CoPs), course information environments (CIEs), domain-oriented design environments (DODEs), Envisionment and Discovery Collaboratory (EDC), PITABoard, DynaSites

1 Introduction

Creativity is often associated with ideas and discoveries that are fundamentally novel with respect to the whole of human history (*historical creativity*). We are primarily concerned with idea's and discoveries in everyday work practice that are fundamentally novel with respect to the individual human mind or social community (*psychological creativity*) [Boden, 1991]. Analyzing the contributions of outstanding creative people [Gardner, 1993] helps to establish a framework for individual creativity, and understanding creativity in the context of social everyday activities is equally important for people to become more productive and create better work products. The analysis of everyday design practices [Rogoff & Lave, 1984] has shown that knowledge workers and designers have to engage in creative activities to cope with the unforeseen complexities of real-world tasks. Creativity happens not only in research labs, but also in daily design activities solving "real problems."

This paper extends earlier explorations and systems instantiating social creativity [Fischer, 1999]. I first characterize design and design communities and differentiate particularly between *communities of practice* (CoPs) and *communities of interest* (CoIs). Externalizations are of critical importance in the formation of these design communities and in their effort to frame, solve, and resolve design problems. I analyze the role of the "right" externalizations (particularly the role of *boundary objects*) in bringing social creativity alive in these design communities. I then describe a number of socio-technical systems that we have developed over the last decade to support social creativity.

2 Design and Design Communities

Design activities, given the nature of their context (wicked problems, change, on-demand, multiple stakeholders), often evolve over long periods of time. Complexity in design arises from the need to synthesize different perspectives of stakeholders on a problem, to manage large amounts of information relevant to a design task, and to understand the decisions that have determined the long-term evolution of a designed artifact. Further, the knowledge associated with a design problem is distributed among the various stakeholders as owners of the problem requiring collaboration among different stakeholders. Design problems are characterized by a *symmetry of ignorance* [Rittel, 1984], meaning that no individual stakeholder, or group of stakeholders, knows all the relevant knowledge, yet the knowledge of all stakeholders is equally important in the process of framing and resolving the problem [Arias et al., 2000]. D. T. Campbell [Campbell, 1969] argues that *"the problem of knowledge must, in the end, be stated at the social level"* and *"the locus of 'truth' and 'knowledge' will have clearly shifted from individual 'minds' to a collective social product only imperfectly represented in any one mind"* (p. 331).

Communication among stakeholders is difficult when they come from different CoPs, and therefore use different languages and different knowledge systems for external cognition. In his book, *The Two Cultures* [Snow, 1993], C. P. Snow describes these difficulties through an analysis of the interaction between literary intellectuals and the natural scientists "who had almost ceased to communicate at all." He wrote that "there exists a profound mutual suspicion and incomprehension, which in turn has damaging consequences for the prospects of applying technology to the alleviation of the world's problems" and "there seems to be no place where the cultures can meet."

2.1 HOMOGENEOUS DESIGN COMMUNITIES: COMMUNITIES OF PRACTICE

CoPs consist of practitioners who work as a community in a certain domain undertaking similar work (although within each community there are individuals with special expertise, such as power users and local developers [Nardi, 1993]). Examples of CoPs are architects, urban planners, research groups, software developers, and end-users. In our past work, we have developed various types of domain-oriented design environments [Fischer, 1994] to support CoPs by allowing them to interact at the level of the problem domain and not only at a computational level.

Sustained engagement and collaboration lead to boundaries [Wenger, 1998] that are based on shared histories of learning and create discontinuities between participants and non-participants. Domain-oriented systems allow for efficient communication within the community at the expense of making communication and understanding difficult for outsiders. For example, over the last fifteen years, we have created concepts, systems, and stories representing an efficient and effective means for communication within our research group. We have also learned, however, that boundaries that are empowering to insiders are often barriers for outsiders and newcomers to a group (the DynaSites system described in Section 5.4 has tried to address this problem). CoPs must be allowed and must desire some latitude to shake themselves free of established wisdom.

Traditional learning and working environments (e.g., university departments and their respective curricula) are disciplinary. Throughout history, the use of disciplines and their associated development of a division of labor have proven to be powerful approaches. However, we also know from all the attempts to support multidisciplinary work that hardly any "real" problems can be successfully approached by a lone discipline [Campbell, 1969].

2.2 HETEROGENEOUS DESIGN COMMUNITIES: COMMUNITIES OF INTEREST

CoIs [Fischer, 2001] bring together stakeholders from different CoPs to solve a particular (design) problem of common concern. They can be thought of as "communities-of-communities" [Brown & Duguid, 1991] or a community of representatives of communities. Two examples of CoIs are (1) a team of software designers, marketing specialists, psychologists, and programmers, interested in software development; or (2) a group of citizens and experts interested in urban planning, in particular with implementing new transportation systems. The Envisionment and Discovery Collaboratory, discussed in Section 5 of this paper, illustrates this last group.

CoIs are "defined" by their shared interest in the framing and resolution of a design problem. CoIs often are more temporary than CoPs: they come together in the context of a specific project and dissolve after the project has ended. CoIs have great potential to be more innovative and more transforming than a single CoP if they can exploit the "symmetry of ignorance" as a opportunity for social creativity.

Fundamental challenges facing CoIs are found in building a shared understanding [Resnick et al., 1991] of the task-at-hand, which often does not exist at the beginning, but is evolved incrementally and collaboratively and emerges in people's minds and in external artifacts. Members of CoIs must learn to communicate with and learn from others [Engeström, 2001] who have different perspectives and perhaps a different vocabulary for describing their ideas, and to establish a common ground [Clark & Brennan, 1991]. Learning within CoIs is more complex and multifaceted than *legitimate peripheral participation* [Lave & Wenger, 1991] in CoPs, which assumes a single knowledge system in which newcomers move toward the center over time. CoIs must simultaneously support a healthy autonomy of the contributing CoPs and at the same time provide possibilities to build on interconnectedness and a shared understanding.

This type of learning in CoIs requires externalizations [Bruner, 1996; Harel & Papert, 1991] in the form of boundary objects [Star, 1989] that have meaning across the boundaries of the individual knowledge systems. Boundary objects allow different knowledge systems to interact by providing a shared reference that is meaningful within both systems. Computational support for CoIs must therefore enable mutual learning through the creation, discussion, and refinement of boundary objects that allow the knowledge systems of different CoPs to interact. In this sense, the interaction among multiple knowledge systems is a means to turn the symmetry of ignorance into a resource for learning and social creativity (exploiting the promise that "innovations come from outside the city wall").

Figure 1 illustrates the relationship between CoIs, social creativity, and boundary objects. The gray large oval represents the design problem that needs to be framed and solved. Four different CoPs (represented by the small circles and the persons with different shaped heads, indicating their different kind of expertise) participate in the collaborative problem-solving activity, but the union of their expertise does not cover the total problem space. Social creativity emerges as the result of collaborative artifact and knowledge construction and it explores and solves new aspects of the problems. New and extended boundary objects increase the shared knowledge.

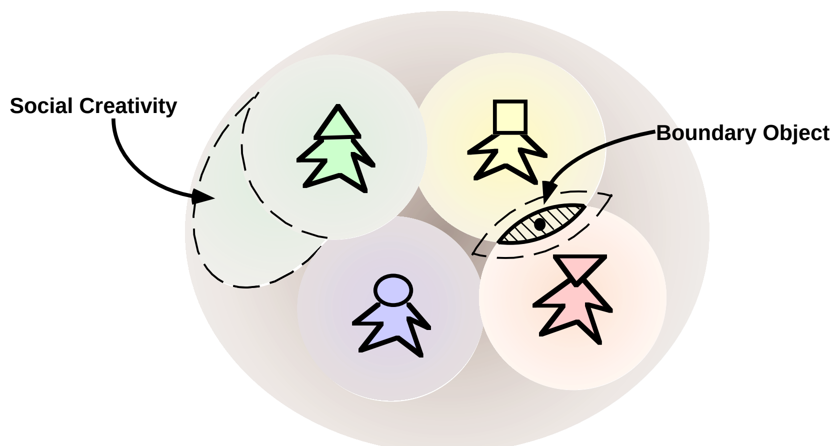

Figure 1: CoIs, Social Creativity, and Boundary Objects

3 Externalizations

3.1 CREATING EXTERNALIZATIONS

An important outcome of shared understanding among CoPs and CoIs is the incremental creation of externalizations [Bruner, 1996] to capture and articulate the *task at hand* [Fischer et al., 1998]. Information is relevant to the task at hand if it (1) helps all participating stakeholders to understand a problem, and (2) is made available when the need for it arises. Externalizations enhance mutual understanding and intelligibility by serving as a resource for assessing the relevance of information within the context of collaboration. In everyday communication, externalizations are often communicated against a rich background of shared experience that is often available only in a very limited form among members of a community. In addition, stakeholders do not like to study large information repositories in the abstract (such as many pages of design rationale, of user manuals, etc.). They are interested in aspects of situations that are directly relevant to their goals and objectives and help them understand problematic aspects of the design situation.

Systems that integrate work tools with information repositories can support a more subtle form of information capture. For example, *social navigation* [Dieberger et al., 2000] and *recommender systems* [Terveen et al., 1997] collect information in the background as users do their work, and then make this information available to a wider community to inform their decision-making processes. These approaches advance the "trailblazer" concept from Vannevar Bush [Bush, 1945] and the "read- and edit-ware" concept from Hill and Hollan [Hill et al., 1992]) to make the following unique contributions: (1) traces are not preplanned aspects of a space, but rather are "grown" (or created dynamically) in a more organic or bottom-up fashion; (2) they provide information that reflects what people actually do rather than what system designers think people should be doing; (3) they rely on the way that people occupy and transform spaces by leaving their marks upon them; and (4) they often rely on the importance of spatial metaphors (e,g, drawing on work in architecture and urban design [Brand, 1995]).

3.2 BOUNDARY OBJECTS: CREATING SHARABLE EXTERNALIZATIONS

Boundary objects [Arias & Fischer, 2000; Star, 1989] are objects that serve to communicate and coordinate the perspectives of various constituencies. For example, different CoPs brought together for some purpose [Wenger, 1998], thereby forming a CoI. In everyday life, we constantly deal with artifacts that connect us in various ways to CoPs to which we do not belong. Boundary objects serve multiple constituencies in situations where each constituency has only partial knowledge (based on the symmetry of ignorance) and partial control over the interpretation of the object. In this manner, boundary objects perform a brokering role involving translation, coordination, and alignment among the perspectives of specific CoPs. It must be understood that the efficiency of the boundary objects in attaining these functions is also contingent on the nature of the constituencies (e.g., their respective level of competency, motivation, and experience).

Externalizations often serve to create "situations that talk back to us" [Schön, 1983]. This "back-talk" will be severely limited by representations that do not serve as boundary objects. Some of the back-talk will be provided by the design situation itself, but this may be insufficient because our ability to notice breakdowns and problematic situations by (visual) inspection and careful analysis is limited. In our research over the last decade, we have developed additional mechanisms to further increase the "back-talk" [Fischer, 1994]: (1) feedback from human stakeholders involved in the design process, (2) computational critics, and (3) simulation components that illustrate the behavior of an artifact. In providing additional feedback, the "back-talk" must be relevant to the actual design situation and must be articulated in a way that the designer can understand. In the construction of shared understanding, the mutually complementary functions behind boundary objects include exploiting the power of the symmetry of ignorance by making the tacit explicit, as well as utilizing the asymmetry of knowledge by eliciting the relevant at the appropriate time. The asymmetry of knowledge means that individual stakeholders possess different, but equally relevant, knowledge.

Boundary objects, as described, can serve two major purposes: (1) they can serve as objects to support the interaction and collaboration among different communities of practice, and (2) they can serve the interaction between users and (computational) environments. In this later case, one can argue that they serve the interaction between the users and the designers (being present "virtually" through the system created by them).

3.3 LIVING ORGANIZATIONAL MEMORIES AS INFORMATION REPOSITORIES FOR SHAREABLE EXTERNALIZATIONS

Living Organizational Memories. Living organizational memories [Ostwald, 2001; Terveen et al., 1995] offer the following promises and opportunities:

- They are information spaces *owned by the people and communities* who use them to do work, not by management or an IT department.
- They support the *collaborative and evolutionary design of complex systems* by providing a means to integrate the many contributions by a large number of people.
- They are *open and evolvable systems*, serving not only as repositories of information, but also as mediums of communication and innovation.
- They are information spaces that can be *evolved through many small contributions made by many people* rather than large contributions by few people (as has been the case for knowledge-based systems of the past).

Unself-conscious Cultures of Design. When users of an artifact are able to recognize and repair breakdowns in use, they are empowered to maintain the fit of their artifact to its changing use environment. Alexander [Alexander, 1964] was an architect and design methodologist who wanted his buildings to be continually maintained and enhanced in this manner by the people who inhabited them. He coined the phrase *unself-conscious culture of design* to describe this form of design-in-use. In unself-conscious design, breakdown and correction occur side by side; there is no formal set of rules describing how to repair breakdowns because the breakdowns were not anticipated. Instead, the knowledge to repair breakdowns comes from the knowledge of the user, who is best able to recognize a lack of fit as well as how the artifact should be changed to improve its fit to the environment.

In an unself-conscious culture of design, the failure or inadequacy of an artifact leads directly to an action to change or improve it. For example, when the owner of a house is also its builder, constant rearrangement of unsatisfactory details are possible. By putting owners of problems in charge, the positive elements of an unself-conscious culture of design can be exploited in the evolution of organizational memories. Open systems provide the enabling conditions for an unself-conscious design culture by putting owners of problems in charge. Breakdowns in such environments are experienced by the end-users and not by the system builders. End-users need the ability to continually and directly evolve and refine their information space, without having to rely on design professionals.

Self-Organizing Evolution. Purely self-organized (decentralized) evolution of complex artifacts and information spaces is a myth [Fischer & Ostwald, 2002; Raymond & Young, 2001]. Social creativity approaches can learn some lessons from open source development projects [O'Reilly, 1999], which always have a core set of "project leaders" who have the final say on the course of the evolution of a project. These people perform centralized integration of information that is contributed by others in a decentralized manner. Contributors are explicitly acknowledged and often assume responsibility for the evolution of their subsystem. Open-source projects have many varieties of control structures, but each project has some centralized responsibility [Raymond, 1998]. None practice purely decentralized evolution.

The evolution of living organizational memories must have elements of both decentralized evolution and centralized integration. The mix of these modes as well as the means of selection of individuals to assume roles of responsibility, takes many forms. The goal of making systems modifiable by users does not imply transferring the responsibility of good system design to the user. In general, modifications that normal users make will not be of the quality of those a system specialist would make. Users are not concerned with the system per se, but in doing their work. On the other hand, users are concerned with the adequacy of the system as a tool to do their work, and as such they experience the fit, or misfit, between their needs and the capabilities of the tool. This is knowledge that the specialist lacks because the specialist does not use the tool to do work. End-user modifiable systems allow the user to adapt a system directly, without requiring a specialist and without requiring deep knowledge of the system's inner workings [Nardi, 1993]. Such systems do not decrease the responsibility or importance of the system specialist, but shift the design emphasis a finished system at design time to a system that can be adapted and modified at usetime.

Sustaining the usefulness and usability of living information repositories over time involves important challenges and trade-offs, summarized in TABLE 1. Such factors depend upon whether these information repositories are evolved by specialists, who do not actually use the systems to do work, or evolved in the working context by knowledge workers, who are owners of problems and who evolve the environments in the context of their work.

TABLE 1: Information Repositories Evolved by Specialists versus Evolved in the Working Context

	evolved by specialists	**evolved in the working context**
examples	digital library of ACM	websites of communities of practice, Eureka
nature of individual entries	database like entries	narratives, stories
economics	requires substantial extra resources	puts an additional burden on the knowledge workers
delegation	possible in domains in which entries/objects are well defined	problem owners need to do it, because the entries/objects are emerging products of work
design culture	self-conscious	unself-conscious
motivation	work assignment	social capital

4 Social Creativity

"Great discoveries and improvements invariably involve the cooperation of many minds!"— Alexander Graham Bell

The power of the unaided individual mind is highly overrated [John-Steiner, 2000; Salomon, 1993]. Although creative individuals [Gardner, 1993; Sternberg, 1988] are often thought of as working in isolation, much of our intelligence and creativity results from interaction and collaboration with other individuals [Csikszentmihalyi & Sawyer, 1995], exploiting the symmetry of ignorance as a source of power. Creative activity grows out of the relationship between an individual and the world of his or her work, and out of the ties between an individual and other human beings [Nakakoji, 1998]. Much human creativity arises from activities that take place in a social context in which interaction with other people and the artifacts that embody group knowledge are important contributors to the process. Creativity does not happen inside people's heads, but in the interaction between a person's thoughts and a sociocultural context [Engeström, 2001]. Situations that support social creativity need to be sufficiently open-ended and complex that users will encounter breakdowns [Schön, 1983]. As any professional designer knows, breakdowns—although at times costly and painful—offer unique opportunities for reflection and learning.

To make social creativity [Fischer, 2000] a reality, we have explored new forms of knowledge externalization, integration, and dissemination based on the observation that the scarce resource in the information age is not information—rather, it is the human resource to attend to this information [Simon, 1996]. One aspect of supporting social creativity is the externalization of an individual's and a group's tacit knowledge [Polanyi, 1966]. Tacit knowledge with individuals means intuition, judgment, and common sense—that is, the capacity to do something without necessarily being able to explain it. Tacit knowledge with groups means knowledge exists in the distinct practices and relationships that emerge from working together over time—the social fabric that connects CoPs and CoIs. Externalizations [Bruner, 1996] support social creativity in the following ways:

- They cause us to move from vague mental conceptualizations of an idea to a more concrete representation of it.
- They provide a means for others to interact with, react to, negotiate around, and build upon an idea.
- They create a common language of understanding (including boundary objects that are understandable across different domains [Arias & Fischer, 2000]).

Social creativity entails taking a new perspective on how we design the supporting technological, social, and organizational environments. Without this perspective, technology to support working and learning is often designed in ways that fail to support social creativity. Organizational aspects (e.g., course structures and curricula in educational settings) are often more concerned with transmitting facts and basic skills and do not adapt well to open-ended problem solving and collaborative learning.

An important prerequisite to bring social creativity alive is that media and environments be available to support meta-design [Fischer & Scharff, 2000]. The perspective of meta-design characterizes objectives, techniques, and processes to allow learners to act as designers and be creative. The need for meta-design is founded on the observation that design in the real world requires open systems that users can modify and evolve. Because problems cannot be completely anticipated at design time (when the system is developed), users at use time will discover mismatches between their problems and the support that a system provides. Figure 2 illustrates the relationships among the symmetry of ignorance, social creativity, and meta-design.

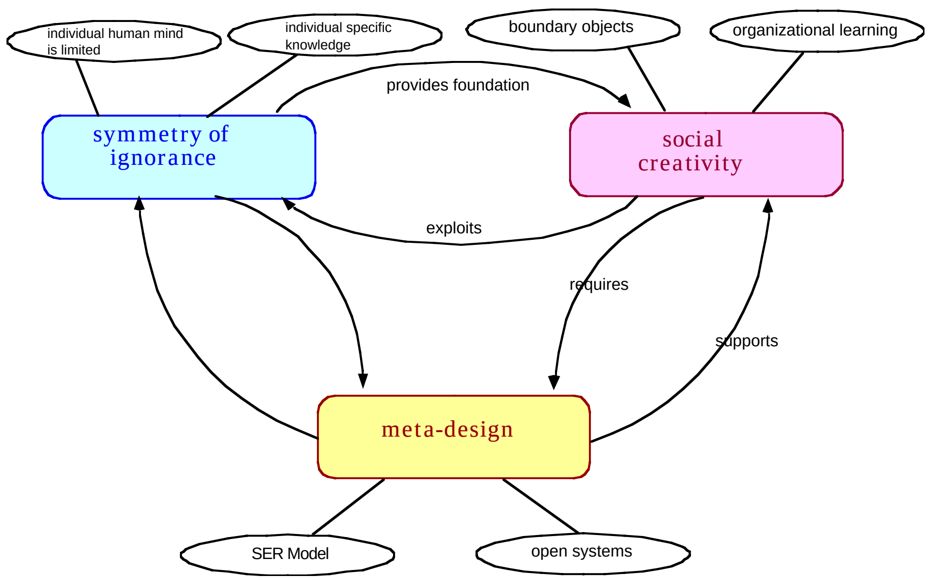

Figure 2: The Relationships among Symmetry of Ignorance, Social Creativity, and Meta-Design

5 Examples of Socio-Technical Environments that Support Social Creativity

5.1 *DOMAIN-ORIENTED DESIGN ENVIRONMENTS* (DODES): SUPPORT FOR TEMPORAL DIMENSIONS OF SOCIAL CREATIVITY

Creativity unfolds and becomes alive in a cultural environment rich with objects that are the products of previous thinking. Domain-oriented design environments (DODEs) are a class of integrated systems that conserve and pass on the “oeuvres” of previous groups (e.g., in the form of palettes, catalogs, and critiquing rules). We have built DODEs in many domains, and during this process we have developed a domain-independent software architecture that describes the tools and knowledge-based mechanisms that support creativity [Fischer, 1994]. Unlike many other computational environments, DODEs can play an active role in the knowledge dissemination process. This is supported by critiquing mechanisms that monitor the actions of users as they work and inform the users of potential problems. If users elect to see the information, the critiquing mechanisms find information in the repositories that is relevant to the particular problem, and present it to the user.

Critics exploit the context defined by the state of the construction, simulation and specification components to identify potential problems as well as to determine what information to deliver. This context enables precise intervention by critics, reduces annoying interruptions, and increases the relevance of information delivered to designers.

Critics embedded in design environments [Fischer et al., 1998] benefit the creative process by increasing the user's understanding of problems to be solved, by pointing out needs for information that might have been overlooked, and by locating relevant information in very large information spaces. Embedded critics save users the trouble of explicitly querying the system for information. Instead, the design context serves as an implicit query. Rather than specifying their information needs, the users need only click on a critiquing message to obtain relevant information. Users benefit from information stored in the system without having to explicitly search for it.

5.2 ENVISIONMENT AND DISCOVERY COLLABORATORY: SUPPORT FOR COPRESENCE DIMENSIONS OF SOCIAL CREATIVITY

The Envisionment and Discovery Collaboratory (EDC) [Arias et al., 2000] is a meta-design effort that supports social creativity by empowering stakeholders to act as designers, thus allowing them to create shared understanding, to contextualize information to the task at hand, and to create boundary objects [Star, 1989] in collaborative design activities [Shneiderman, 2000]. The EDC framework is applicable to different domains as we demonstrate here by applying it to (1) courses taught at schools and universities; (2) professional communities ranging from those in assistive technology development to designers in architecture and urban planning; and (3) different communities to support their lifelong learning efforts. Figure 3 shows part of the current prototype of the EDC (which explored urban transportation planning as an application domain). The EDC attempts to leverage the powerful collaboration that can take place in face-to-face settings and augment this collaboration with boundary objects. The EDC integrates our previous research work in simulation, decision-support, and domain-oriented design environments.

Figure 3: The Current Prototype of the EDC

5.3 PITABOARD: SUPPORT FOR DIFFERENT PROCESSES IN CREATING EXTERNAL AND SHAREABLE ARTIFACTS

Initial prototypes of the EDC were based on a touch-screen technology (SmartTech's SmartBoard) placed in a horizontal orientation that afforded insight into important aspects of around-the-table interaction. In working together, participants have to coordinate both the content created jointly and the process employed in the creation of the content [Clark & Brennan, 1991]. The assessment of the initial prototype of the EDC uncovered several limitations, such as the lack of simultaneous interactions and the inability to create interaction behaviors more closely tailored to the objects with which the participants are interacting. To address these limitations, we are currently studying the use of a technology created for use in electronic chessboards (by DGT Projects, Netherlands) that allows several objects (with embedded transponders) to be tracked simultaneously (see Figure 4). Our current prototype, the Participate-In-The-Action Board (PITABoard) [Eden, 2002], supports the following new forms of interaction:

- parallel interactions (rather than single-threads of interaction and errors when multiple accesses are attempted);
- multiple "points of control" (rather than a single interaction cursor);

- sensing pieces automatically when placed on board (rather than needing to explicitly press the piece onto the surface).

Figure 4: Designing a Public Transportation System with the PITABoard

TABLE 2 compares the support for collaborative design activities between the EDC and the PITABoard environment.

TABLE 2: Comparing the EDC and the PITABoard Environment

Limitation observed with EDC prototype	New capabilities afforded by the PITABoard	Characteristics of new capability	Interesting applications
touch-screen technology requires that users take turns	parallel interaction possible	allow more natural conversational flow of group interaction	allow individual subgroups to work independently
single cursor leads to use of generic "select-object / select-action / perform-action" interaction style	each piece acts as a cursor, creating a broader repertoire of interaction styles	supports various types of interaction: (1) place & track, (2) place & leave, and (3) draw,	place & track: objects move through the simulation; place & leave: rubber stamp
users have to take explicit actions to make the physical-virtual connection	piece automatically sensed when placed on board	more transparent, direct interaction	closer linkage between the physical and virtual worlds
users need an abstract mental model to guide the interaction	extend EDC capabilities with new interaction techniques	more concrete interaction techniques are possible	lower threshold for those unfamiliar with computers

5.4 DYNASITES: COLLABORATIVELY CONSTRUCTED, LIVING INFORMATION REPOSITORIES

As designs evolve, so do the associated knowledge systems. DynaSites [Ostwald, 2001] is an environment for creating and evolving web-based information repositories. DynaSites serves as the substrate for the EDC's reflection space, and also as a stand-alone knowledge system. DynaSites houses several different kinds of open-ended information spaces including: (1) threaded discussion forums, which might be owned by a particular community or might house discussion of a specific issue; (2) Sources, a shared repository for such literature references as journal articles, conference proceedings, and web sites; (3) the CommunitySpace, which holds persona pages for each DynaSites user (personas are intended to help users establish an identity within DynaSites and to help find others with whom to collaborate, based on mutual interests or complementary experiences); and (4) DynaGloss, a shared glossary of terminology open to all DynaSites users, who can annotate terms or redefine them when desired [Fischer & Ostwald, 2002].

Integration in DynaSites. DynaSites supports CoIs with shared information spaces (e.g., sources, DynaGloss) that act as boundary objects in the integration of individual information spaces (e.g., discussion forums). This helps CoIs to identify overlaps and differences in their use of vocabulary and literature references. All information in DynaSites is evolvable, so it provides an environment in which shared terminology and meanings can be developed and negotiated over time.

The boundary objects are realized as hyperlinks that bridge information spaces by creating links between them (see Figure 5). Perhaps the most important of these are the "term" links, which enable DynaGloss to automatically integrate information across the entire DynaSites repository. For example, suppose the term, "knowledge system" was defined in DynaGloss, and also appeared in entries (shown cross-hatched in Figure 5) of both Forum A and Forum B. A stakeholder reading the entry in Forum A would see "knowledge system" represented as a link. Upon selecting the link, this stakeholder would be brought to the "knowledge system" entry in DynaGloss that contains a definition as well as a listing of all uses of the term throughout DynaSites. Included in this list would be a link to the entry containing "knowledge system" in Forum B. By following this link, the stakeholder would be likely to find a discussion relevant to Forum A, but possibly expressing a different perspective. Finally, the stakeholder might follow the persona link for the entry in Forum B and become acquainted with a new collaborator from a different CoP.

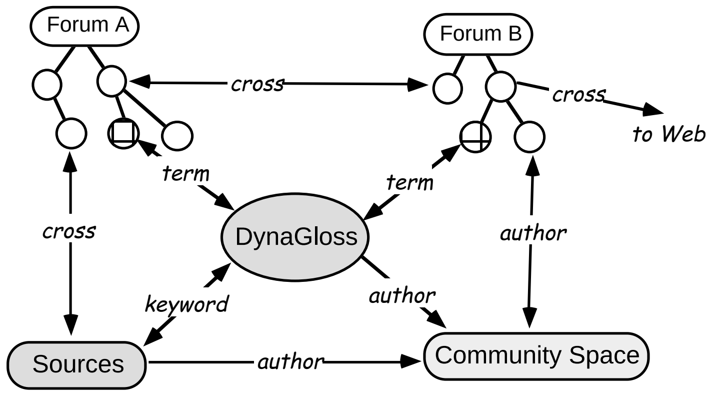

Figure 5: DynaSites Integration

The various linking strategies illustrated in Figure 5 create a rich web of information that represents interactions between different knowledge systems. While most of the links are automatically created and updated by the system, information must be represented in a manner that the system can interpret. For example, terms must be spelled identically to be matched with glossary entries. The overall quality and integration of the DynaSites information space requires effort and attention to detail that is beyond simply entering information. Without care, the information space can become unwieldy after a period of evolutionary growth [Fischer et al., 2001]. One of the research issues we are investigating with DynaSites is how much extra effort members of CoIs are willing to put into the task of entering information and what the different components of this effort are [Grudin, 1994].

5.5 COURSES AS SEEDS

In our long-term efforts to support social creativity, we reconceptualize courses as *seeds* rather than as finished products. The basic objective is to change one of the most impoverished paradigms of education, namely a setting in which “a single, all-knowing teacher tells or shows presumably unknowing learners something they presumably know nothing about” [Bruner, 1996]. Despite the fact that significant efforts are under way to change the nature of school discourse to make it more of a collective inquiry [Scardamalia & Bereiter, 1994], this traditional model of education is still widely practiced in our educational institutions, leading such critics as Illich [Illich, 1971] to claim that our schools and universities are the "reproductive organs of a consumer society" and that "people who are hooked on teaching are conditioned to be customers for everything else."

The traditional paradigm of education is not appropriate for understanding and learning to resolve the types of open-ended and multidisciplinary design problems that are most pressing to our society. These problems, which typically involve a combination of social and technological issues, require a different paradigm of education and learning skills, including self-directed learning, active collaboration, and consideration of multiple perspectives. Problems of this nature do not have “right” answers, and the knowledge to understand and resolve them is changing rapidly, thus requiring an ongoing and evolutionary approach to learning.

As an alternative to the traditional educational paradigm, we envision courses as communities of learning in which participants shift among the roles of learner, designer, and active contributor [Rogoff et al., 1998]. The predominant mode of learning is peer-to-peer, with the teacher acting as a "guide on the side" rather than as a "sage on the stage." Courses are reconceptualized as seeds that are jointly evolved by all participants rather than as finished products delivered by teachers [dePaula et al., 2001]. The content of our courses is centered around design problems and activities. These problems do not contain answers that can be found in textbooks or derived in a semester, but instead are complex, vague, and open-ended problems. Within our model, students are designers and reflective practitioners who must frame the problems they will investigate [Schön, 1983]. The knowledge to understand, frame, and solve design problems does not exist a priori, but is constructed and evolved by exploiting the power of the "symmetry of ignorance" and "breakdowns."

A New Culture of Education. The courses-as-seeds model [Fischer et al., 2001] represents a system of values, attitudes, and behaviors that is radically different from the traditional educational culture in which courses are conceived as finished products and students are viewed as consumers (see TABLE 3). It aims to create a culture based on a “designer mindset” [Fischer, 2000; Resnick, 1994], which emphasizes habits and tools that empower students to actively contribute to the design of their education (and eventually to the design of their lives and communities).

TABLE 3: Contrasting Courses as Seeds with Courses as Finished Products

Courses as finished products	Courses as seeds
learners answer problems given to them by the instructor	learners construct knowledge about topics that are personally meaningful
learners interact mainly with the teacher and compete with other learners for grades	learners are a community of practice that collaborates to build shared understanding
learners are complete novices in the subject matter and make no contribution to other students	course participants are knowledgeable in their own working environments and have much to offer
a course is given over a period of years, more or less in the same form	a course is considered as a seed that will evolve continuously in future courses
learners are recipients of knowledge (the assumption is that the teacher/instructional designer has all the relevant knowledge)	learners are not just passive recipients of knowledge, but active contributors (i.e., they actively co-design the class curriculum)

Course Information Environments (CIEs). Rather than using technology to "recreate education as it is," we have conceptualized educational technologies as CIEs that support the following activities:

- *Learning discourse and social capital:* CIEs should not be passive repositories of information, but rather "living" information spaces [Terveen et al., 1995] through which members of a learning community can share ideas and build social relationships. To become an active member of a community means to build networks and to learn about and contact other members of the community with similar interests, ideas, and goals; that is, it means to "learn to be."
- *Building, referring, extending:* As opposed to merely delivering existing and prefabricated information to students, CIEs should afford learners the opportunities to extend the current state of knowledge, or an idea expressed by a peer, by contributing from their particular areas of expertise. The goal is not just an accumulation of information, but a collaborative construction of new knowledge.
- *Formalizing, restructuring, reusing:* The "products" of each course contribute to a larger accumulation of information relevant to the course. The point is not that a CIE will hold answers to questions, but rather that it should contain resources that allow the next class to generate new ideas—to go beyond where they could have gone if they had started from scratch.

Because CIEs are persistent, they can serve as a source of assessment and reflection of course activities. Based on the courses-as-seeds model, the CIE for a given course should show the following characteristics:

- a growing and evolving information space, driven by course activities;
- student-initiated contributions indicating personal interests and reflections;
- rich interaction among all participants, as opposed to strictly between student and instructor;
- knowledge building, including extensions to the original seed as well as to new ideas contributed by participants; and
- discussions and artifacts that can be incorporated into the seed for the next course in a reseeding process.

Examples of CIEs collaboratively created by all course participants (teachers and learners) can be found at:

- http://www.cs.colorado.edu/~l3d/courses/atlas-2000/ — a CIE developed with the DynaSites substrate [Ostwald, 2001];
- http://webguide.cs.colorado.edu:3232/atlas — a CIE developed as a Swiki [Guzdial, 2000]

Lessons Learned from the Assessment of Our Courses. Data from questionnaires regarding the two courses showed that our initial attempt to promote social creativity was at best a limited success. For example, students viewed the class discussion forum based on DynaSites as a means to submit homework assignments, but not as a means to interact with their peers. Responses indicated that many students remained unconvinced of the value of self-directed, peer-to-peer learning. They continued to consider themselves as consumers of education, expecting the instructor to lecture predetermined and well-defined materials. Their behavior was grounded in the following beliefs (illustrated with quotations from students):

- Learning is a one-way process in which students are strictly recipients—“The main feeling that I get from this course is that we are heavily pressured for feedback.”
- Problems have an answer and that the teacher has to know the answer—“Why should I pay fees if the teacher is not willing to provide me with the answer?”
- Students were at best not interested, and at worst unwilling, to engage in peer-to-peer learning—“Why should I learn from a peer when the faculty member knows the answer so much better?”
- Unwillingness to share—“The weakness in DynaSites is that some people may see what others are writing for their responses and copy the answers!”

We believe that the assessment problems associated with social creativity are critical and multifaceted.

6 Conclusions

"The strength of the wolf is in the pack, and the strength of the pack is in the wolf." — Rudyard Kipling

External and shareable artifacts are important ingredients to support social creativity. Without boundary objects and without making information relevant to the task at hand, CoIs will be severely limited in their collaborative design activities.

Research in social creativity encompasses both technical and nontechnical processes. While new technologies are important and necessary for progress, but they are not sufficient. Social creativity forces us to transcend individual perspectives. Until recently, computational environments focused on the needs of individual users. As more people use computers for more complex tasks, environments that support social interactions among CoPs and CoIs are increasingly needed. However, this perspective does not necessitate the development of environments in which the interests of the group inevitably supersede those of the individual. Individuality makes a difference, and communities get their strength to a large extent from the creativity and engagement of the individuals. One of the important challenges for the future is to gain a better understanding of the relationship between the individual and the social.

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- *"Social Creativity and Meta-Design"*, May 2001, Aspen (for details, see: http://www.cs.colorado.edu/~l3d/l3d-sra-naist-may2001/).

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