Communities of Interest: Learning through the Interaction of Multiple Knowledge Systems

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Abstract. Complex design problems often cannot be solved by individuals or by homogenous groups. *Communities of interest (CoIs)* (defined by their collective concern with the resolution of a problem) bring together stakeholders from different *communities of practice (CoP).* Reaching a common understanding between these stakeholders is a major challenge due to the "symmetry of ignorance" caused by their respective cultures and their use of different knowledge systems. Our research has focused on the development of conceptual frameworks and innovative socio-technical environments to exploit the "symmetry of ignorance" as a source for social creativity among CoIs.

1 Introduction

Design projects and designed artifacts [Rittel, 1984; Schön, 1983; Simon, 1996], given the nature of their context (wicked problems, change, unique characteristics, and multiple stakeholders) often evolve over long periods of time. Complexity in design arises from the need to synthesize stakeholders' different perspectives of a problem, the management of large amounts of information relevant to a design task, and understanding the design decisions that have determined the long-term evolution of a designed artifact. The knowledge associated with this type of design problem is distributed tacitly among the various stakeholders, each of whom possess an important and yet incomplete understanding of the problem. This distribution of knowledge, characterized as a *symmetry of ignorance* [Rittel, 1984], implies that communication and mutual teaching and learning are among the most important activities in framing and (re)solving design problems.

Communication among stakeholders is difficult when they come from different communities of practice (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."*

In our work we try to address the challenges of collaborative design involving stakeholders from different practices and backgrounds by promoting a constructive interaction between multiple *knowledge systems*. This article associates multiple meanings with "knowledge systems" (the theme of IRIS24): *computational knowledge systems* are explicit externalizations of our internal, tacit, *conceptual knowledge systems.*

Over the years, our Center for LifeLong Learning and Design (L^{3}D) (http://www.cs.colorado.edu/~l3d/) has brought together many diverse cultures including the following CoPs: (1) people from academia and from industry, (2) software designers and software users, and (3) students and researchers from around the world. We have designed conceptual frameworks and innovative socio-technical environments to create learning and working environments in which social creativity can come alive through the interaction of these diverse communities.

2 Design Communities

Design communities are increasingly characterized by a division of labor, composed of individuals who have unique experiences, different interests and perspectives about problems and who use different knowledge systems in their work. Shared understanding [Resnick et al., 1991] supporting collaborative learning and working requires the active construction of a knowledge system in which the meanings of concepts and objects can by debated and resolved. In heterogeneous design communities such as those that form around large and complex design problems, the construction of shared understanding requires an interaction and synthesis of several separate knowledge systems.

2.1 Homogenous design communities: communities of practice (CoPs)

CoPs consist of practitioners who work as a community in a certain domain undertaking similar work (although within each community there are individual with special expertise, such as power users and local developers [Nardi, 1993]). Examples of CoPs are: architects, urban planers, research groups, software developers, and end-users. In our past work, we have developed various types of *domain-oriented design environments* [Fischer, 1994] supporting 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 knowledge 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 is the boundaries that are empowering to the insider are often barriers for outsiders and newcomers to the group (the DynaSites system described below tries to address this problem).

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 proved to be a powerful approach. 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.

2.2 Heterogeneous design communities: communities of interest (CoIs)

"Innovations come from outside the city wall."

CoIs 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. Examples of CoIs are: (1) a team interested in software development that includes software designers, marketing specialists, psychologists, and programmers, or (2) a group of citizens and experts interested in urban planning who are concerned with implementing new transportation systems, as illustrated later in the paper by the Envisionment and Discovery Collaboratory.

CoIs are characterized 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 can exploit the "symmetry of ignorance" as a source of collective creativity.

Fundamental challenges facing CoIs are found in building a shared understanding 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. Learning within CoIs is more complex and multi-faceted than *legitimate peripheral participation* [Lave & Wenger, 1991] in CoPs, which assumes that there is a single knowledge system, in which newcomers move toward the center over time.

This type of learning in CoIs requires *externalizations* [Bruner, 1996] in the form of *boundary objects* [Star, 1989] which 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 between multiple knowledge systems is a means to turn the symmetry of ignorance into a resource for learning and social creativity (because innovations come from outside the city wall).

Our own institution, the University of Colorado at Boulder, is engaged in a number of innovative efforts to bring different communities together as learning organizations by creating the right mix of CoPs and CoIs:

- the *Alliance for Technology, Learning, and Society* (http://www.colorado.edu/ATLAS/) is building new innovative collaborations and learning opportunities between arts, humanities, science, engineering, and new media to support these collaborative efforts and express new ideas.
- the *Institute of Cognitive Science* (http://psych-www.colorado.edu/ics/) has struggled for a long time with the question of whether it should become a department (thereby emphasizing the CoP dimension), but eventually decided to remain an institute bringing representatives of different departments together (meaning that the CoI nature was considered more important).
- the *L^3D center* has established itself as a CoP based on a shared history and the use of concepts and system developments as shared reference points. At the same time, we strongly believe that CoPs must be allowed and must desire some latitude to shake themselves free of existing wisdom and therefore we make every conscious effort to exploit the strengths of CoIs. While we have a center, we do not maintain it as a fixed entity, but engage in activities to extend it and to embrace new ideas, new people, new collaborations, and new media. We try to apply our ideas and frameworks about design—e.g., to consider *"design as a dialectic process between tradition and transcendence"* [Ehn, 1988; Morch, 1997]—not only to the development of the systems we build, but also to the design of work practices and spaces that can bring social creativity alive.

3   Examples of Knowledge Systems Supporting CoPs and CoIs

Socio-technical environments (including abstractions, domain models, tools, design methodologies, etc.) embody a group's or culture's intellectual history: they have theories and basic assumptions built into them, and users accept these (most of the time unknowingly) when they use these tools. Cognition, value systems, and preferences are not only shared among minds, but also among minds and the structured medium and externalizations with which minds interact. Knowledge systems supporting CoPs provide cognitive economy to a particular professional community, but they may be of little or no use outside of this community. CoIs use and rely on *multiple* knowledge systems and

multiple centers that emerge and shift during collaborative learning and working activities (for example: websites created by artists look very different from websites created by computer scientists).

3.1   Support for CoPs: *domain-oriented design environments*

Domain-Oriented Design Environments (DODEs) [Fischer, 1994] are a class of integrated systems that provide substantial support for individual creativity and some limited support for social creativity. We have built DODEs in many domains, and during this process have developed a domain-independent software architecture.
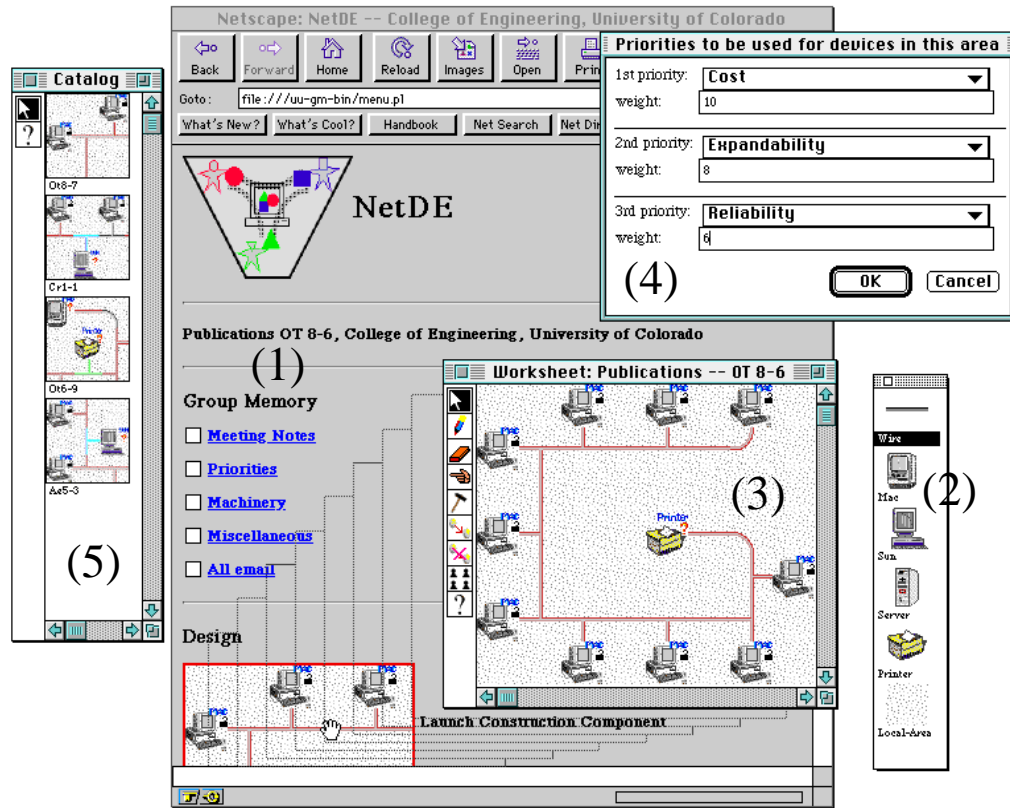

Figure 1. A DODE for Computer Network Design.

DODEs support a particular domain, assuming that artifacts created will have a substantial similarity. DODEs encourage conformity with the rules and norms of the domain, and support sharing of domain knowledge among a community of users. DODEs

assume that users will interact indirectly (through the system and the artifacts stored in them) rather than face to face. Figure 1 shows a screen image supporting the CoP of computer network designers.

DODEs are not just reactive (or passive) knowledge systems, but they are *proactive (or active)* systems [Sullivan, 1995]. This behavior is supported by *critiquing mechanisms* that monitor the actions of users as they work, and inform them about potential problems. 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 user must 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.

A primary focus of DODEs was to provide a rich channel of communication between the user and system. Collaboration between users was considered to take place indirectly through the artifacts, a much narrower channel. We found that this indirect channel of communication had several advantages within CoPs, including the fact that interactions could be captured and associated with the artifacts to which they referred. We also found that indirect communication was not sufficient to support the kind of communication and learning required by CoIs, who require as broad a channel of communication as possible.

3.2   Support for CoIs: the Envisionment and Discovery Collaboratory

The Envisionment and Discovery Collaboratory (EDC) [Arias et al., 2000] addresses some of the shortcomings of the first generation DODEs. The EDC allows for face-to-face interaction (maximizing the communication channel between stakeholders), mediated by both physical and computational objects. The EDC supports CoIs by empowering all stakeholders to (1) to create shared understanding, (2) to contextualize information to the task at hand, and (3) to create boundary objects in collaborative design activities.

The EDC consists of an *action space* in which the actual designs are created and a *reflection space* [Schön, 1983] containing associated knowledge systems that describe the artifact under construction (including design requirements, design rationale, related

information, etc.). The EDC framework has been applied to different domains including: (1) courses taught at schools and universities [dePaula et al., 2001], and (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 2 shows the current prototype of the EDC that explored urban transportation planning as an application domain.

Figure 2. The current prototype of the EDC.

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 the 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 participants are interacting with. To address these limitations, we are currently studying the use of a technology created for use in electronic chessboards (by DGT Projects, NL) that allows several objects (with embedded transponders) to be tracked simultaneously (see Figure 3).

Figure 3. The "Chessboard" Environment.

Table 1 summarizes the differences between DODEs and the EDC.

User Communities	Problems and Artifacts	Knowledge Development	Interaction	Support
CoPs	different tasks in the same domain and a uniform representation	refinement of one knowledge system	indirect (through systems and artifacts)	DODEs
CoIs	multiple domains and different representational schemes	synthesis and mutual learning through the integration of multiple knowledge system	face to face, mediation by physical and computational objects	EDC

Table 1. Differences between DODEs and the EDC.

3.3 DynaSites: collaboratively constructed, living information repositories

As designs evolve, so do the associated knowledge systems. DynaSites [Ostwald, 2000] 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

which might house discussion of a specific issue; (2) *Sources*, a shared repository for literature references, such 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.

DynaSites support 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. Since all information in DynaSites is evolvable, it provides an environment where 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 4). Perhaps the most important of these are the "term links" that 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 4) 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, she 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, she might follow the persona link for the entry in Forum B and become acquainted with a new collaborator from a different CoP.
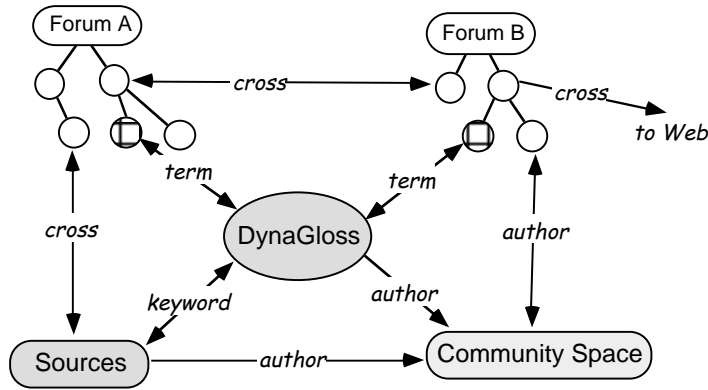
Figure 4: DynaSites Integration

The various linking strategies illustrated in Figure 4 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, 1998]. 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].

4   Conclusions

CoIs, by bringing different CoPs together, provide unique opportunities to bring social creativity alive by transcending individual perspectives. Until recently, computational environments focused on the needs of individual users. As more people use computers for more complex tasks, it has become apparent that environments supporting social interactions among CoPs and CoIs are needed.

Our research has evolved from (1) empowering individuals to (2) supporting CoPs with DODEs to (3) creating shared understanding among CoIs with the EDC and DynaSites. In this "journey", we have not abandoned earlier themes, but we have widened our focus and have learned how different computational and conceptual knowledge systems fit together and complement each other.

5 Acknowledgements

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