3 OPEN COLLABORATORIES FOR DESIGN INNOVATION

How can the collective intelligence of distributed individuals be utilized towards cooperative research and design of product innovations for sustainable development? While distributed online peer-production has been effective for lightweight forms of information gathering and technically savvy developers of open source software have managed to form distributed but “socially closely-knit” communities, there are many challenges in distributed cooperation for knowledge-intensive design innovation across social and institutional boundaries. What is the role of collaboration tools and platforms for distributed peer-production among global communities in knowledge-intensive domains? How should such platforms support knowledge exchange, production, peer review as well as facilitate social awareness and communities of practice?

Online Collaboration Tools and Repositories

There is a wide array of commercially available web-based collaboration tools such as Microsoft NetMeeting and Groove as well as simple online community publishing tools such as Wiki Wiki Web or Twik that support editable webpages and Movable Type for creating personal weblogs. While web-based design and modeling tools such as PTC and Dome provide powerful collaborative features, they tend to be geared towards high-end engineering design and simulation by technically savvy users, rather than being positioned as open public domain platforms for lightweight design interaction. Relevant components of many such design and publishing tools could be integrated into a general collaboration platform. There are online repositories for open source software like SourceForge.net and Savannah run by the Free Software Foundation. Finally there are a number of community portals for knowledge exchange. The World Bank’s Development Gateway is a portal for exchange of information on international development projects among a community of domain experts and practitioners worldwide.

The goal of ThinkCycle is to provide a platform for distributed communities to engage in cooperative design and peer production across diverse disciplines and institutional boundaries. Most collaborative tools are developed for use by teams within institutional settings, while recent software repositories enable distributed developers to work on open source projects. However, scientific research and design collaboration among a global community requires a broader framework for cooperative platforms, which allow diverse forms of contribution, exchange, peer-review and learning. ThinkCycle is emerging as a collaborative platform, open design repository and global community for sustainable design innovation.

3.1 Distributed Computing and Knowledge Production for Global Challenges

A number of experiments in distributed computing have been undertaken in recent years to use the computing capacity of networked machines for solving problems such as finding keys to data encryption algorithms (distributed.net) and even searching for extraterrestrial life. SETI@home is a distributed computing initiative setup by physicists and researchers at the University of California, Berkeley as an experiment in “public-resource computing” [Anderson2002]. Before SETI@home, special purpose supercomputers were used to analyze radio signals from space telescopes and seek out narrow-bandwidth signals that are not known to occur naturally (which would provide implicit evidence for extraterrestrial technology). In 1995, researchers proposed using thousands of networked computers worldwide to analyze SETI signals. In 1998 the group released desktop client software for PCs and Macs to download data, analyze and return processed results regularly. By August 2002, millions of users worldwide had downloaded the

24 http://www.groove.net
25 http://www.c2.com
26 http://twiki.org/
27 http://www.movabletype.org
28 http://www.ptc.com/
29 http://cadlab.mit.edu/research-dome/
30 http://savannah.gnu.org/
31 http://www.developmentgateway.org
32 http://setiathome.ssl.berkeley.edu/
client programs and thousands of them formed teams to compete within categories. While the initiative has so far not found evidence of extraterrestrial life, it has demonstrated the viability of public-resource computing for complex computational challenges. Interestingly, the SETI@home users have formed a community facilitated by an online site setup by the researchers, which includes project updates, ongoing discussions among users and their contributions of software or documentation.

Other distributed computing projects include prime number searchers (GIMPS project), protein folding (folding@home at Stanford University) and drug discovery (Intel-United Devices Cancer research project). Several academic initiatives have been undertaken for public resource computing including The Global Grid Forum\(^33\) for resource sharing among academic and research organizations, as well as private initiatives such as Entropia\(^34\) that develop distributed computing platforms for problems such as drug discovery and protein folding. Applications best suited for such distributed computing initiatives must exhibit several factors [Anderson2002] including high computing-to-data ratio (keeping network traffic at a manageable level), independent parallelism (or modular and asynchronous analysis) and tasks that tolerate high errors (so that minor errors in any distributed process do not corrupt the overall analysis). Several projects such as global climate modeling and ecological simulation have been proposed. Besides the computational objectives of these initiatives they have an important role in creating public awareness of global problems in the sciences, and an implicit means for people to contribute.

A recent example of a knowledge-based distributed initiative is OpenLaw\(^35\), an experiment in collaborative development of legal arguments [Lefkowitz2002]. The experimental project was setup by the Berkman Center for Internet and Society at the Harvard Law School. It is open to both lawyers and the general public; it provides relevant documents regarding legal cases and discussion tools to allow users to interact and propose potential arguments, and find weaknesses in each others strategies before cases are brought to court. The first OpenLaw case, Eldred v. Ashcroft, challenges the Sonny Bono Copyright Term Extension Act – Congress’s recent 20-year extension of the term of copyright protection -- on behalf of publishers and users of public domain works. The Supreme Court heard the case on Oct 9, 2002, argued by Stanford law faculty, Lawrence Lessig. Though the outcome was not in their favor, the case (and perhaps the open process) created a great deal of publicity and public awareness of the critical intellectual property issues involved in the case. The project founders cite a democratizing motive “by using the Internet, we hope to enable the public interest to speak as loudly as the interests of corporations.”

Another example of a distributed design initiative was setup to solicit ideas for Sudden Infant Death Syndrome (SIDS). Robert Cringely who lost his son to SIDS, proposed the idea of a simplified health monitor to warn caregivers of patient symptoms. Volunteers initiated an online community site\(^36\) to coordinate the project, which has already received contributions and ideas from thousands of people. Lefkowitz considers these initiatives “ant hill communities” that emerge in online networks from the collective intelligence of distributed individuals. The SIDS project comes closest to the sorts of cooperative initiatives that ThinkCycle is intended to support i.e. to enable many such “ant hill communities” to be formed around critical global problem domains.

The notion of distributed knowledge-intensive problem solving has been a working practice in the scientific community, even before the advent of email and collaborative technologies. Since email and networked access have become more prevalent, collaborative scientific initiatives have emerged more readily. In the late 1980’s the notion of “Collaboratory” emerged in discussions among the scientists at the National Science Foundation and National Research Council; Collaboratories were defined as a “center without walls” [Wulf89] for geographically dispersed teams to conduct research and share resources, remote tools, databases and instruments. Gary Olson [2002] considers collaboratories as a new means for organization of scientific activity, where the constraints of distance and time are mediated through collaborative technologies and

\(^{33}\) [http://www.gridforum.org/]
\(^{34}\) [http://www.entropia.com]
\(^{35}\) [http://eon.law.harvard.edu/openlaw/]
\(^{36}\) [http://www.chasecringely.org]
practices. Olson feels that the emerging global challenges such as HIV/AIDS epidemics necessitate international scientific cooperation, though their attempts at collaboratory projects at the University of Michigan\(^{37}\) indicate that not all communities are ready for this form of collaboration. Olson finds that to effectively participate in collaboratories there needs to be greater readiness in three critical dimensions of collaboration, infrastructure and technology. He finds that many science communities are highly competitive and do not have a culture of knowledge exchange established in the context of their institutional settings, thus they exhibit lower level of collaboration readiness. Despite access to networked infrastructure and communication technologies, there is a normal progress (and training required) for the adoption of technologies from simple email and online repositories to that of advanced collaboration tools. Thus it is necessary to assess the state of collaboration readiness among communities and organizations involved to ensure success.

Olson points out a number of factors to mitigate risks in the adoption of collaboratories including user-centered iterative design of the collaboration tools, ensuring acceptable speed and reliability of increasingly complex technologies, as well as training and learning from users at early stages of the design and deployment. From experiments they find that allowing students to participate in collaboratories with senior researchers (in their own or different institutions) provides a kind of engagement and motivation best described as “legitimate peripheral participation”, not afforded to them in normal circumstances. The participation of senior scientists through virtual seminars and peer review also broadens the access to their own scientific practice among junior researchers providing them greater feedback and opportunities for publication and grant funding. The serendipitous encounters online among researchers may escalate potential for scientific collaborations, particularly across disciplines. Hence collaboratories may emerge as new forms of social organizational in science if the participants are able to adopt and engage in these online environments in meaningful ways.

Olson’s group conducted an assessment of online collaboration support for two cooperative HIV/AIDS research projects involving the Harvard Medical School, the Ministry of Health in Botswana and the University of Oxford, U.K. Though they find high degrees of collaboration readiness with established procedures and practices, there is less experience with collaboration tools and implementing new collaboration technologies would require not only training but also “reinterpreting established ways of working together”. There is a need to familiarize project members with social and cultural norms (such as trust and ethics) helping establish “common ground”. In Africa even when collaboration infrastructure is available the communication networks tend to be unreliable at different times of day, hence requiring collaboration tools that operate at low bandwidth with highly compressed data and asynchronous connectivity with pre-caching content. Pricing structures for network connectivity including per-minute fees affect the choices for media and tools used and hence the nature of collaboration. For example, though instant messaging (IM) is prevalent in the US, lack of persistent connectivity makes it less widely used in Africa, however phone-based asynchronous SMS messaging is extremely popular there. Overall, with most HIV/AIDS research originating in western countries, African researchers and students find themselves at a disadvantage to keep up with progress in the field and be part of the scientific mainstream. Collaboratory initiatives can enhance international scientific collaboration among researchers and practitioners in developed and developing communities but also regional interactions among researchers in neighboring countries, as seen in the Botswana case.

How should one develop online platforms that support the emergence of global collaboratories in critical problem domains? Clearly one must make such platforms accessible in both developed and developing countries and support the social networks forming across institutional settings. Next I will describe how ThinkCycle addresses some of these issues including infrastructure, tools and social mechanisms to support collaboration. In later chapters we will examine the nature of design interaction, learning and intellectual property issues that emerge in such collaboratories.

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\(^{37}\) http://www.scienceofcollaboratories.org
3.2 ThinkCycle: Open Collaboratory for Sustainable Design Innovation

The ThinkCycle platform was developed as a shared online space for engineers, domain experts and stakeholders to discuss, exchange and construct ideas towards design solutions in critical problem domains. ThinkCycle provides a web-based collaboration framework that supports individuals and organizations in seeking, documenting and sharing information about problem domains and emerging design. It is largely a self-organized and decentralized system, allowing individuals to create online communities of interest around specific domains and contribute or learn from ongoing discussion and design activity.

Problem domains or Topics created by participants include cholera treatment devices, human power generation, neonatal care for rural settings, and household water treatment systems. Topics consist of an online discussion board, shared file-space, categorical notes and publications. Organizations and domain experts typically post design challenges and resources, while design teams use the system to post iterative design concepts, technical notes, working files and images. Other participants, including the stakeholders, innovators and the general public review the ongoing design on ThinkCycle while posting their own contributions. The topic creators initially serve as editors, to set up the problem domain and make suggestions to contributors when needed; however no formal moderation mechanism is created on the system. Contributions within a topic, called notes, are variously categorized as challenges, concepts, resources, technical notes, experts and organizations. These notes consist of short text descriptions, along with online links and attached images and files. Subscribers to specific topics are notified by email whenever new content is posted to the topic. All content can be peer-reviewed, searched and cross-linked to any other content on the site.

Although topics are designed for knowledge sharing, we have recognized the need for supporting the distinct design activities of different teams working on such topics. Hence, one recent component developed, ThinkSpaces, provide a shared space for members of design teams within topics to share and collaborate towards evolving design concepts. It serves as an informal online design notebook for each team. Design teams may choose to work privately, or to share their design notes publicly allowing peer-review for rapid design iterations. The tools will be extended in the future to provide visualizations of the design process, and better support for collaborative engineering design tasks.

![Figure 3.1: Knowledge sharing and collaborative design activities among diverse users on ThinkCycle.](image-url)
3.2.1 Architecture and Implementation

The ThinkCycle online collaboration platform was developed using an open source framework based on the *ArsDigita Community System* (ACS)\(^{38}\). It consists of services and modules for managing content, versioning, permissions, user membership, messaging, session tracking, and user-interface components. Custom applications for ThinkCycle are developed in the *Tcl* programming language with SQL queries, as modular software packages running on an Oracle database for creating shared project spaces, posting content, uploading files and images, discussions, peer-reviews, tracking user history and a custom search engine. The system allows members to set access permissions and track multiple versions for any content posted.

The Oracle database is backed-up to a secure fileserver on a daily basis. The web-servers are continually monitored by several custom processes written in *Perl* to ensure the server is always up and running with minimal CPU load. We also maintain a separate development server\(^ {39}\) for prototyping and testing new applications and features. Finally all content files in the Oracle database are extracted four times a day (in an XML-like format using *php* scripts) to a separate mirror server\(^ {40}\), which provides fast text-only access to archived files categorized under topics. The mirroring system was developed by Jason Taylor, a graduate student at the MIT Media Lab. The mirror archive can be subsequently placed on distributed servers around the world, for rapid access by universities and local users. This infrastructure provides a robust and scaleable online platform for a large distributed community worldwide.

To support sharing of knowledge among such distributed communities, ThinkCycle provides a number of key collaboration features in a web-based online platform. Here I summarize the key features, before we consider the applications developed in more detail.

- **Topics**: categorization taxonomy for problem domains and evolving solutions. Topics provide a shared space for discussions, contributions, resources, files and publications.

- **Publishing Contributions**: Users can submit content to topics in the form of categorical notes like challenges or design concepts with file attachments, images and online links. All content posted can be cross-linked to other content on the site, emailed or commented on by others users.

- **Dynamic Views of New Content**: The system tracks all items contributed by users and content posted since their last visit to the site. Users can browse selective views of new content submitted. Content can be sorted by many different attributes.

- **Access Control**: Content owners can set permissions on any contribution to allow others edit privileges, as well as basic privacy settings to allow selected users to view content. Topic editors can edit/delete any content posted in their topics.

- **Threaded Discussion Boards**: Users can subscribe to any topic discussion forum and post messages online with file attachments. Discussion boards can be moderated.

- **File Management and Archiving**: Every topic provides a file-space for uploading files, with versioning features and search. All files are archived daily on distributed mirror sites.

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\(^{38}\) The underlying ACS software framework (4.x) used to develop *ThinkCycle* is unfortunately no longer available, since the company that developed it, *ArsDigita*, went out of business in February 2002. A different software framework, *OpenACS*, was released by some of the core developers of ACS in Fall 2002 as an open source project available at http://www.openacs.org. However, the source code and software packages developed on either system cannot be easily migrated among different versions of ACS without significant work.

\(^{39}\) *ThinkCycle Development Server*: http://thinkcycle.media.mit.edu:8000/

\(^{40}\) *ThinkCycle Mirror Server*: http://thinkcycle.media.mit.edu
- **Peer-Reviewed Digital Library**: Allows users to add papers with bibliographic information to any topic and allows other users to submit detailed peer-reviews for any papers. Finally, authors can comment on paper reviews online as well.

- **Custom Search Engine**: Allows rapid keyword searches of site-wide contributions on ThinkCycle, as well as refined searches based on topics, files and notes categories.

- **ThinkSpaces**: Project repositories for distributed design teams, with public and private access to content posted. This serves as a means to archive, manage and track ongoing design iterations by team members and allow selected individuals to review the content.

### 3.2.2 Designing for Collaborative Communities

The design of the ThinkCycle platform evolved to support essentially three main functions for collaborative communities: **personalization**, **social awareness** and **shared content management**.

#### A. Personalization

While anyone can browse content on the site, registering as a member, allows users to access many personalized features. All pages on the site are dynamically generated based on content posted as well as properties of the member logged in. The system keeps track of when the user last visited the site and shows all new postings the next time they login. The system bookmarks the last Topic and ThinkSpace visited and provides a navigation bar with quick access to all related subsections of the topic i.e. discussions, filespace, papers, notes and images. This navigation tool improves the ability for users to browse the site very easily, as it aggregates all components (each running as independent software modules) of a recently selected topic. Users can subscribe to any topics on the site and receive email notifications whenever new content is posted. The **Workspace** allows members to set subscriptions, personal settings and view the history of all content they posted over time. The system also allows users to set a text-only display option to navigate the site without images under low-bandwidth requirements.

![Feature Image](image.png)

**Figure 3.2**: The navigational menu displays personalized information when members log in. The floating **Topic Navigator** remembers the Topic and ThinkSpace last visited and provides rapid access to all topic subsections.

![Image](image.png)

**Figure 3.3**: The front page shows the “Featured Topic” (automatically selected from recent postings) and new Topics, ThinkSpaces, concepts and challenges submitted.
B. Social Awareness: When members login, the system shows the last dozen members who recently visited the site as well as specific topics or categories of topics on the site. It also shows members who are currently active online while users are logged in. Users can see the last Topic and ThinkSpace members visited as well as their contributions on the site. They can directly email members through the site with a protected messaging system, which allows members to prevent spam (undesired email) from non-members. This provides a sense that the site is more than a content archive but a rich social space, with both a history of members’ visits and interests as well as live interaction. Over time, this “social awareness” allows members to notice patterns i.e. when others login and what topics they tend to frequent. The “SoapBox” is a recent community application that allows free-form postings and chat among members called “rants”, with recursive commenting on all postings (rants on other rants). It also shows the most popular rants posted over time. This turns out to be the most regularly utilized outlet for ongoing informal dialogue among the community – a kind of online “community pulse”.

C. Shared Content Management: Members can setup Topics of broad interest to the community, which include their own discussion forum, file storage, publication library and project spaces (ThinkSpaces). Multiple editors can be set to edit/remove content as needed, though there is no formal moderation process. Within the topic different types of notes such as challenges, concepts and resources can be posted. Each note contains a summary, online links, attached files and images. Members can add comments, cross-links (to other content posted elsewhere on the site) or email the notes to others. The note creator can also set access privileges to grant selective read/write/admin permissions to selected members as needed. All notes can be sorted by a number of attributes including date, comments or number of visits etc (providing a measure of popularity). Finally ThinkSpaces within topics provide private project spaces for design teams.
Figure 3.5: (a) List of all topics under various categories like health, education, energy etc. The system displays all postings and recent visitors within each category. (b) Main page for the “Cholera Treatment Devices” topic, containing the related categorized notes like concepts, challenges, resources etc, as well as discussions, member subscribers, filespaces, publications and ThinkSpaces setup for the topic.
Figure 3.6: (a) A private ThinkSpace setup by a design team working on the passive incubator project. (b) A concept description in response to a challenge posted, with ongoing comments and links by peers.
3.2.3 ThinkCycle: Design Evolution of the Collaborative Platform

The ThinkCycle platform evolved from an early concept prototype to a robust and scalable system over a period of 2 years. While the system was not architected with a unified vision at the onset, its design was shaped by ongoing usage and feedback from the online community. Here I describe three main stages of its development, along with the emerging design rationale, technical challenges, user interaction and social issues arising in the process of iterative design.

I. Concept Prototype: Online Problem-Solution Repository

The early vision of ThinkCycle was to develop an online database that allowed anyone to add well-posed “challenges” (problem statements) and “concepts” (design solutions) into an open public repository that could be easily accessed and searched. At this stage, ThinkCycle was primarily positioned as an online problem/solution repository for students and faculty to work on real-world challenges in engineering design courses, as well as members of field organizations who presumably had “technical design problems” that needed to be solved. The initial interaction model was envisioned to be one of student designers in universities working on selected projects for nonprofit clients on the field, rather than a cooperative learning experience for a diverse range of individual and organizations. The key goal was to document as many challenges in the database rapidly for students to solve in their courses, and hopefully have subsequent design solutions later documented on the site, which would all be publicly accessible online.

The first concept prototype was developed in summer 2001 as a collaborative effort among the founding members of the ThinkCycle initiative. The prototype was developed using an early version of Zope, a web-based content management system (CMS) that provided a simple scripting interface for building a web application. The first prototype provided a means for people to register online, add files and images to their personal folder, post challenges and concepts as textual descriptions with images, as well as search content posted. While the system provided a good proof-of-concept, it was not robust (crashed frequently) and neither the system nor its implicit data structure was easily scaleable for large number of online users and content posted. All data was stored as objects and serialized into a binary file system; hence unlike a relational database, the data could not be easily inspected, queried or manipulated. In addition, while the CMS framework was considered open source, only source code for some application packages was available rather than the underlying kernel, hence significant changes could not be done to customize the system or address systematic problems. This prototype was subsequently abandoned after several months of effort to make it stable. However, the lessons learned later allowed us to select a more robust platform and specify better design criteria for a future system.

II. Early Functional System: Formalized Content Structure and Community Tools

While the first concept prototype demonstrated the potential for an online problem-solution repository, it was not clear how such a system would scale as diverse content would be contributed by different users. In an attempt to better understand the necessary structure and design requirements, we initiated a product design studio at MIT in spring 2001. The goal of the studio course was to bring together an interdisciplinary mix of engineers, designers and domain experts to work on real-world design problems (related to the environment or underserved communities) posed by stakeholders in field organizations. Concrete design projects in a studio setting provided a better sense of the potential structure and requirements for an online system to support the course. While projects were solicited among field organizations, they could be categorized into generalized “Topics” or problem domains of interest. Within these topics many challenges, resources, concepts, technical notes etc needed to be listed. Hence a topical structure for the content and a taxonomy of contributions (or “notes”) within each emerged.

41 http://www.zope.org
The second attempt at developing ThinkCycle was initiated mid-way through the design studio in mid-April 2001, while many team projects were already underway. There was a clear recognition that an online system was needed to allow teams to document ongoing project information and design files, while making it accessible to the remote stakeholders participating in these projects. After a close examination of web-based platforms available at the time, we decided to deploy the system on an open, robust and scaleable system consisting of an Oracle database, AOL web server and the ArsDigita Community System (ACS), an open source web-based content management system. All source code for ACS application modules (packages) and the system kernel was easily available, and the system had been used extensively to develop industrial strength commercial websites, such as the WGBH portal (Boston-based TV station) and the World Bank Development Gateway. Some ACS modules and tools by third party developers were available as open source packages, such as user directories, photo-albums, and system administration tools. These distinct packages were initially modified and integrated into a coherent web-based application that served as the underlying framework for ThinkCycle.

**Taxonomy of Topics and Notes**

Several custom applications with the necessary database structure were developed to support the structure and interaction desired for the ThinkCycle community of users. The first early version of the new system was released in mid-May 2001 for use by students in the design studio. The core application developed initially allowed users to setup Topics of interest, which automatically generated associated file-storage, discussion forum and photo-albums for images. The topic creator would be designated as the topic “editor”, however initially the editor had no specific privileges to moderate content within the topic; hence editors primarily served only symbolic roles. Later the system permitted multiple editors to be designated to each topic with read/write privileges to edit or remove content posted. Users could create multiple topics, each with a taxonomy of chronologically ordered notes categorized as challenges, resources, tech-notes, concepts, organizations, experts, events, and courses. Any note posted could be specified with a category, title, and description, along with optional URL, file-storage to attach relevant documents and files as well as a photo-album for related images. Each note could also be edited, deleted and moved to other topics. Finally users who created notes could give read/write or admin permissions to other users to modify their notes as well. All URLs are verified by the system before notes are permitted for posting, to ensure no broken links are ever submitted to the site. The notes posted were automatically emailed to the author and any subscribers of the topic. Any note could be linked to other content on the site such as topics, notes and publications. The system tracked when the user last visited the site, hence any new content posted since the last visit could be shown. As the online file-system was initially slower than expected, all files within each topic were archived in a separate text-only website for fast access, updated 4 times a day. A custom search engine was developed for queries within topics or specific categories of notes.

**Digital Publication Library**

In the summer of 2001 we hosted an international workshop\(^{42}\) at MIT on sustainable design and technology, on the heels of the design studio conducted that spring. The workshop was setup as a peer-reviewed forum, with papers submitted by all participants. A specialized application was developed on ThinkCycle to serve as a digital repository for papers submitted as well as an open peer-review system. The system was tested in the process of running this workshop, with nearly 80 papers submitted and dozens of reviews posted by the workshop program committee as well as the general public. Both papers and reviews could be setup as public or private access only, allowing the authors and reviewers sufficient flexibility in the manner in which they wished to participate in the workshop online. In many cases authors who initially set their papers to private access, later made them public for reviews. The system was improved for the 2nd conference\(^{43}\) held in 2002, with faster access, papers on a mirror site, and a means for authors to comment on paper reviews received. The publication library is now a generalized module available to all topics on ThinkCycle, allowing each to maintain its own distinct collection of peer-reviewed articles.

\(^{42}\) [http://www.thinkcycle.org/dyd](http://www.thinkcycle.org/dyd)

\(^{43}\) [http://www.thinkcycle.org/dyd02](http://www.thinkcycle.org/dyd02)
Figure 3.7: An earlier version of the ThinkCycle interface. a) Front page with new postings as well as recent topics and challenges, b) Topic section with different categories of notes shown; however the overall structure, spatial layout and information clutter was confusing for novices.
III. Towards a Cooperative Design Platform for Distributed Communities

Iterative Visual Redesign and Supporting Informal Interaction

The prototype system was much improved and optimized in the fall of 2001 and spring 2002, based on user feedback and usage by a growing distributed community. While the initial system had a great deal of useful functionality, users often found the interface complex and confusing. This was partly due to unfamiliarity with a new mode of interaction and content publishing in an online medium, but more importantly due to a mismatch in the mapping of the visual interface to their design tasks as well as a poor spatial organization of the relevant interface elements. Over a period of several months of iterative user feedback from nearly hundreds of distributed users, the system features and interface layout was gradually refined, while common interface and visual conventions were established on the site to make the overall usage much more intuitive. The visual interface design and layout of ThinkCycle was successively revamped nearly 4-5 times over a period of 16 months, until the system reached a level of technical stability and design coherence such that users were able to focus on posting design content and there were minimal bugs reported. Many applications were simplified and the interface made less structured to allow both novices and regular users to interact more easily in an informal manner. Users could comment on notes or papers posted and interact informally using ThinkSpaces and the SoapBox.

ThinkSpaces for Project Teams

The Topic sections of the site provided a broad online community and space for sharing relevant resources, discussions, and publications; however over time it became clear there was a need for specialized project spaces within Topics. Several design projects conducted by different teams could be initiated within topics and required distinct online spaces for archiving and sharing project related resources. ThinkSpaces were developed as a separate module integrated within Topics such that any user could setup one or more collaborative projects. The system allowed the creator to setup Public or Private ThinkSpaces with access granted to selected team members or other contributors. Each ThinkSpace generated an associated discussion forum, file-storage, and allowed users to post different categories of notes (similar to Topics). Notes could also be shown at the topic level at any time if needed. This allowed project teams to maintain a private space and gradually add content, while making selective portions of the project publicly accessible.

Personalization for Members

The system was successively designed to provide additional personalized features for members. Only registered members were allowed to access to member emails, previous pages visited by other members and send them messages. Members could subscribe to any topic or ThinkSpace to receive automatic email notifications on content posted. All member contributions were easily accessible and listed chronologically in their workspace. Members could set their display setting to text-only mode to view the entire site without images and a text-only menu, for low-bandwidth access or printer-friendly display. Finally the system tracked the last topic and ThinkSpace visited by the member, showing a floating navigational menu with quick access to topic sub-sections. The system remembers the settings, subscriptions and bookmarks for each member, revealing them on their subsequent visits, hence personalizing the site for individual users.

SoapBox for Informal Rants

The discussion forums in topics and ThinkSpaces seemed to be the least active, as many users either preferred to discuss projects over email or found that there was not sufficient critical mass in topics to initiate discussions. In addition many users felt that the topics and ThinkSpaces were somewhat too formal to post impromptu and ad-hoc messages that were not always well suited to existing topics of interest. The SoapBox was developed as a distinct module that allowed informal postings (or “rants”) by members or even anonymous users. Responses may be posted to these rants in a recursive manner (rants posted on rants) and are emailed to the original authors. Popular rants with most responses were listed on the SoapBox, while new rants since

44 http://www.thinkcycle.org/soapbox/
their last visit could also be shown. Finally, the SoapBox could be used in chat-mode, such that it is updated online frequently with responses shown in real-time (“SoapBox Live”). This application was adopted very quickly by the users on the site, particularly novice and anonymous users, who seemed to find it a less intimidating and intuitive means to gradually get involved on the site. The Titles of new rants posted on the SoapBox are featured on the frontpage, while the number of rants posted each week or since the user’s last visit are prominently shown in the top left corner of the website at all times, both acting in effect as a social “pulse” of the online community.

This cumulative set of applications provide most of the features requested by users; integrating the technical infrastructure and visual interface among these applications into a coherent online community system with an intuitive interface has been a major challenge for ThinkCycle.

3.2.4 Case Study on Collaborative Design: Cholera Treatment Devices

Let's examine a case study to demonstrate how one design team used the system in the Design that Matters course offered in spring 2001, to archive their work and collaborate on a problem domain related to cholera treatment. This interdisciplinary design team consisted of three MIT engineering students, working closely with a local domain expert to explore design approaches for cholera treatment devices. This case study illustrates the design process, emerging design artifacts and outcomes of the project. However, we must note that the ThinkCycle system became available to the design team only in the second half of the design course.

The key design challenge was to develop a novel low-cost IV drip flow control device that would facilitate rapid treatment of patients infected with cholera. Cholera is an acute intestinal infection, which if left untreated can lead to severe dehydration and death. The team began with a basic survey of cholera epidemics and how medical relief organizations currently handle such treatment, particularly in refugee camps where a large number of patients must be treated quickly. In this exploratory problem-formulation phase, the team archived some of the online articles, resources, organizations and established designs as categorical notes on their ThinkCycle topic. Based on their online discussions with domain experts and relevant literature search, the team developed four well-posed challenges for cholera treatment, which were clearly documented on the site.

The team quickly moved into the design phase of the project, experimenting with existing IV drip measurement devices and their own prototype devices. They archived the flow-rate data results of their experiments as documents and excel spreadsheets on the ThinkCycle filespace, often sharing the uploaded documents with each other and the course instructors in this manner. The team now devised clear design constraints for their
proposed devices based on their target users (medical relief assistants in developing countries), which included low cost, accurate flow-rates, ease of operation and simplicity of construction. In a series of group meetings the team came up with a diverse set of 7-10 concept alternatives, followed by concept sketches, detailed design specifications, prototype manufacture and experimental testing of the prototypes. Many of the design artifacts from this process, including sketches, graphs, CAD models and images were archived on ThinkCycle with annotated comments. In some instances, other students in the course and the local domain expert reviewed these artifacts and provided feedback to the team. The team now found their nine working design concepts fell in three categories of increasing complexity, and began to evaluate the design constraints for each device based on the criteria proposed earlier. Designs that showed most promise included a modified roller clamp and a rotameter (an instrument for measuring fluid flow rates); these were more extensively refined and tested, while additional documentation regarding their design rationale and advantages/limitations was archived online on a separate website designed by the team.

Finally, the team took their design sketches and working prototypes to consult with two doctors at the Massachusetts General Hospital Division of Infectious Diseases. Both doctors had extensive field experience with cholera treatment. The critical feedback from the doctors helped the team understand some of the real world constraints for practitioners and narrow their designs accordingly. The team videotaped and summarized the discussion, which was subsequently archived on ThinkCycle.

The team submitted their final paper for the dyd01 workshop at MIT, which was archived and peer-reviewed in the ThinkCycle publication library [Prestero2001]. In March 2002, the team was contacted by representatives from a healthcare company in the US, to license their innovations for production. The team is currently working closely with the MIT Technology Licensing Office (TLO) to obtain three patents on their innovations before pressing further with commercial licensing. Following the first public disclosure, US intellectual property law allowed the students up to a year to patent their designs. While the team can negotiate appropriate licensing agreements with commercial manufacturers in the US, the designs remain in the public domain for the rest of the world. It remains to be seen how the open source process and mechanism of patents can coexist, and to what extent either supports innovation and field deployment.

We will closely examine the intellectual property issues involved in this project in chapter 5 of this thesis, based on an ethnographic study with the student innovators. Understanding the role of

45 http://www.mit.edu/~tprester/DtM/
intellectual property rights in collaborative design settings is important to ensure access to the innovations in critical domains as well as reciprocal benefits for innovators. While the ThinkCycle online system implicitly registers all user contributions towards design posted on the site, we must recognize to what extent it would seem appropriate to consider an explicit policy or social contract that helps resolve intellectual property concerns among distributed contributors.

### 3.2.5 Interaction between Social and Technical Spheres in Online Design

The ThinkCycle online software system facilitated the design process in a different manner among localized and distributed participants. Students involved in the design studios at MIT and Bangalore conducted much of their design activity in physical hands-on settings with face-to-face interaction among group members. Some resources and project designs were archived on the site gradually to document and provide online updates to potential contributors, however a majority of the design work was never archived on the site. Hence the social process of design continued to a great extent outside of the technical platform, while portions of the design activity would become visible online which team members were willing to report publicly for a broader audience. In some cases, individuals working alone often archived many informal resources and designs in ThinkSpaces online, however they discontinued doing so when there was insufficient interest and feedback from the online community. Hence, the nature of design activity expressed online primarily served either as a group memory of recent work or to solicit feedback from online peers. As the task of adding content online was generally an added overhead for most, and their team members were available physically, online interaction was not considered a priority among localized team members. However when some team members were away in remote locations or domain experts distributed, these situations prompted greater interaction online. Among the distributed community using ThinkCycle (outside classroom settings), the online spaces provided a means to setup and solicit interest in potential problem domains and design projects. Several such online challenges and project spaces have been setup on ThinkCycle by distributed participants. These often involved less intensive work and a slower pace of design, however even small contributions (comments and resources) provided over time continued to support the design process. Here the social process is firmly embedded in the technical system.

Hence a dual socio-technical system seems to emerge, which operates differently among localized and distributed communities. The social process of design among localized teams operates at an intense pace with frequent face-face interactions in physical space over a period of time. This process is augmented by an online system through asynchronous archiving of content and information updates at irregular moments, typically paced by physical events such as meetings, presentations or deadlines. While among a distributed community, the entire social process typically happens online mediated by interactions using email and ThinkCycle. The intensity and pace of interaction tends to be slower and stretches over a much longer period of time, based on the interest of online peers and emerging information relevant to the project. Thus online systems like ThinkCycle are used in a different manner by co-located and distributed participants, with distinct benefits and limitations for either group. These two types of groups sometimes interact in shared online spaces, often leading to extended dialogue on the site and rapid iterations in the design process. In particular, events like workshops and conferences, where participants submit papers that are peer-reviewed online, extend the social space among this distributed community as they find themselves intensively interacting with others through the site. The social ties established in these brief transactions often extend into other cooperative interactions elsewhere on the site over longer periods of time. In many cases physical events like the dyd conferences bring some of the distributed participants together, strengthening social ties in face-to-face settings, which provide a basis for enhanced online interaction in the future.

Finally, the nature and definition of “communities” on ThinkCycle is somewhat difficult to recognize. It was earlier envisioned that so called “communities” would be formed around Topics (or problem domains) of interest. However it generally seems that there is a broader sense of community among ThinkCycle members (or at least a portion of them) that usually cuts across topics of interest. One finds users subscribed and contributing to many topics rather than being confined to one or two only (though they may start there). There is low level of online discussion.
observed within topics, while the SoapBox tends to be far more active. This indicates that topics of problem domains do not define communities on the site, however action projects like ThinkSpaces or the dyd conference and informal areas cutting across topics like the SoapBox develop and sustain “social collectives” and the broader ThinkCycle community. A majority of ThinkCycle members and anonymous users do not regularly post content or engage in ongoing discussions, acting as “lurkers” browsing information on the site on an irregular basis. ThinkCycle members use and perceive it in different ways at different times as: 1) a cooperative platform with members or groups developing and archiving design challenges and projects, 2) a learning and problem solving area for students and experts contributing or commenting on content posted, 3) an information archive for members or anonymous users acting as lurkers seeking or searching content, and 4) an open social space for members being aware of others throughout the site, learning about their interests and communicating with them through the site. Hence there are many different interaction modes and social spaces (brief and informal vs. extended and formal) emerging on the site, based on the particular interests and needs of users at different times.

3.2.6 Lessons Learned: Key Design Challenges and Principles

I now summarize several key design challenges and design principles emerging from the development of the ThinkCycle platform, and observation of its social usage among local and distributed participants. A more in-depth analysis emerged from the online survey and interviews I conducted with participants in May-Sept 2002, which is described in the next chapter (4) of the thesis. Clearly many of these lessons are specific to the context of open collaborative design within a platform primarily used in university settings, however I believe many of these issues are applicable towards a broader set of collaborative design tools and online community platforms.

- **Simplicity and integration of the user interface to support natural interaction.** While there was a great deal of functionality provided for collaboration, most users desired simplified modes of interaction and intuitive structure to browse and contribute to the site.

- **Asynchronous design interactions archived online are valuable for design teams.** The system provides an ongoing repository of resources and intermediate designs that can be easily searched, cross-linked and commented. The online space represents an evolving group memory, which complements face-to-face and synchronous activities.

- **Integrating content from existing modes of communication and working environments.** Many users continue to exchange ideas and project information over email, and often desired an ability to post content to the website directly from email. In some cases users wanted to place sketched drawings, CAD models or images onto the site effortlessly. Hence existing forms of communication and work habits must be integrated somehow.

- **Recognizing the need for effective solutions for users with low-bandwidth access.** Many users, particularly in developing countries have slow dialup connections where they must pay per minute. Hence, rapid text-only display and email-based updates are needed.

- **Supporting brisk and lightweight interaction for rapid design transactions online.** Most designers involved in product design process are not accustomed to documenting their work online regularly. They desire a rapid means to quickly document ongoing design concepts and resources, without much overhead; this is a critical aspect for adoption.

- **Providing sufficient structure to allow communities to organize themselves online.** It is a tremendous challenge to develop a structure that supports the existing design process of users in an online system, while generalizing it and making it scaleable for hundreds of distributed design teams who may wish to utilize the online system for diverse projects.

- **Allowing informal and unmoderated interaction to support open and unfettered dialogue.** It became clear that many people did not participate in the online discussion forum or post content regularly as they felt the structured topics required formal and well-posed
content, hence there was need for informal and unstructured online forums such as the SoapBox and ThinkSpaces to encourage spontaneous interaction.

- **Social norms and conventions among communities of practice emerge over time.** While the online system imposes some constraints and allows a multiplicity of possibilities for structuring interaction, the participants engaged in using the system regularly establish norms, while novices recognize them over time. Conflicts occur when participants have different expectations or if these norms and conventions change unexpectedly.

- **Product design within a team is a social process** where design decisions are negotiated and members made aware of ongoing progress; hence social mechanisms for awareness, access and iterative design among participants must be supported.

- **Allowing users flexibility in protecting or disclosing their intellectual work as desired over time.** While the system tracks content and allows selective access to teams, novel models of intellectual property agreements are needed to promote cooperative design.

To support distributed online communities for cooperative design, the collaborative platforms must be intuitive for use by diverse participants, permit both structured organization as well as opportunities for informal dialogue, and allow low-bandwidth access via email and asynchronous modes integrated into existing working environments and design tools. In addition, the system must be setup such that it is truly “open” to allow sophisticated users and groups to access content in multiple ways, design appropriate features, applications, interfaces and customize the system according to their own needs (see examples of prototype applications in figure 3.12). This requires setting up common access protocols such as XML or RDF for data in the underlying database, and providing simplified mechanisms for scripting or customizing applications online. The social incentives for using an online system in the design process by localized or distributed communities include lack of easily available domain expertise, peer-contributors not co-located with design team, clear value attributed for archiving projects online (e.g. course grades or peer-review by interested parties), and low perceived overhead for regularly posting content. Projects that exhibit such attributes may be better suited for cooperative online interaction on ThinkCycle.

We now consider the nature of design rationale, social context and physical settings in shaping cooperative design outcomes using such online platforms.

![Figure 3.12: Two examples of desktop applications for ThinkCycle: (a) ThinkCycle Lite: an educational interface for school children (developed in Shockwave), and (b) ThinkCycle@home: a working prototype for asynchronous access to personalized content (developed in Java). Both are documented on ThinkCycle.](image-url)
3.3 Capturing Evolving Design Process and Rationale

Understanding Design Rationale: Studies and Tradeoffs for Designing Tools

The primary output of a design process tends to be a specification of the artifact, rather than information about why it is constructed or the design assumptions used. A design rationale is an explanation of the reasoning, tacit assumptions, design parameters, operating conditions, dependencies or constraints applied in the creation of an artifact or some part of it [Gruber93]. A design rationale may help justify why specific decisions were made and alternatives chosen in the process of design. It is argued that design rationale is helpful for both the original designers and others in reusing, modifying and maintaining the existing designs. It is also considered useful for designers to communicate and coordinate within a team over time or negotiate with stakeholders about a design in progress.

3.3.1 Observations about Design Rationale from Design Protocol Studies

Gruber and Russell [1992] surveyed and conducted many design protocol studies of designers requesting, communicating and using design information (individual designers were observed thinking aloud or discussing prior design with members of a team). They noted many observations about how designs are explained in documents and live discussions:

- Questions asked by designers included many different information sources (documents, CAD tools, spreadsheets, informal notes) and subjects (requirements, constraints, structure, expected behavior and intended function). Hence the scope of information is very broad; not easily captured in any one artifact or subject alone.
- Though many frameworks for recording and representing rationale exist (design as argumentation, design as decision making, design as constraint satisfaction), no single model accounted for a majority of the questions. In addition, the language of the protocol required designers to reinterpret natural explanations in terms of the protocol (e.g. "issue", "option", "constraint"). Hence a preconceived model of the design process, embodied in a tool is inadequate for capturing the broad scope of natural and informal design rationale expressed in the course of a design process.
- Rationales are often constructed and inferred in response to questions asked in redesign, rather than stored as complete answers in the design record. Hence it is more important to capture relevant data than to try and anticipate the potential questions and answers.
- Rationale explanations often describe dependencies among decisions or design parameters. Dependency relations are important in managing change in designs. Hence it is useful to capture such dependencies or inferring them from information captured.
- Gruber and Russell found in examining the questions/answers in the protocol studies that much of the information used in rationale explanations could be found in sources (textbooks, databases) available to the practicing engineer or by reference to engineering/simulation models. Hence in addition to rationale provided by the designer, hypertext linkage to online sources and databases of real engineering data and models would play an important role in constructing rationale explanations.
- Although facts mentioned in rationale explanations come from formal models and engineering data, justifications for design decisions tend to be informal. Most justifications were weak explanations such as lists of factors considered rather than strong ones describing how factors led to a decisions or deductive proofs. This is not surprising as designers in the protocols studied were conversing in natural language. Such weak explanations if relevant are indeed useful to designers, sometimes more so than strong formal explanations. Hence they suggest that it is more important to capture the relevant set of facts from the designer (to reconstruct a rationale) than to assemble a coherent argument at the point of capture.

Gruber and Russell suggest that existing software tools for engineering design should be extended to support easy capture or linkage to rationale explanations as a by-product of their
usage. Relevant information from many sources should be informally captured during the design process where possible rather than focusing on a preconceived models for capturing complete and coherent rationales, and leaving an explanation of how such elements justify design decisions to the reader.

3.3.2 An Empirical Study of Design Rationale in Engineering Practice

It is important to consider how rationale explanations might be used in actual engineering practice to recognize what information to capture, how it should be captured and its impact on collaborative design. An empirical study of design rationale documents related to product engineering was conducted at a French aerospace company [Karsenty96]. The study examined several questions: (1) Do designers confronted with unknown design need to know the design rationale? (2) How do they use design rationale documents? (3) And do we succeed in capturing rationale that designers are looking for using existing methods? From an extensive review of various types of questions asked at design meetings, they inferred that the nature of questions in design sessions are spontaneous and context-dependent whereas design rationale questions are more important where designers work on previous designs with much historical knowledge of the project. They found that engineers used design rationale in two different ways: looking at the rationale opportunistically after having examined product blueprints earlier to gain a better understanding of the artifacts as well as extensively where they would examine the reasoning and then the solutions in the blueprints. They used rationale to seek out problems raised in the design, and as a means to support their own reasoning about the problem. The authors infer that more experienced designers, used an opportunistic mode of inquiry, while constructing their own explanations, while others unfamiliar with the project required an extensive reading.

The authors propose an iterative approach to capturing design rationale, suggesting that it should be conceived of as an unfinished “document” that evolves over the course of a project and certainly improved as questions are raised by subsequent use of the rationale by others. The peer review process in ThinkCycle should enable such iterative improvement of the rationale. The authors cite a “social approach to design memory” [Bannon96], where the emphasis is on dialogue in work settings for people to collectively interpret past experience and influence others interpretations. They suggest that technical solutions embodied in collaborative applications may not be sufficient for use of design rationale, in addition new work organizations should also be defined. Thus the question of how existing institutional settings support the capture and active use of rationale, and how they should be extended to do so is worth examining. For example, in ThinkCycle there is an explicit interest in having student design teams collaborate with distributed domain experts and stakeholders, which creates a new social and institutional setting for capture and use of rationale.

Finally the authors highlight a common false assumption that “every design has a rationale”, making the idea of “capture” possible. This assumption may indeed be false for many projects, however where rationale can be expressed, it still seems valuable both for pedagogical use and iterative redesign in a different context. Another assumption is one of a static “design space” of possibilities that can be readily analyzed by designers; Such a design space would not be fixed in time but would evolve over time and would change based on the experience and background of other designers. Hence many questions about rationale may not be readily addressed in the original design, requiring an iterative approach for capturing potential rationale from others not directly involved in the original design.

We need to consider how an online engineering collaboration platform such as ThinkCycle supports capture and representation of design rationale in the process of design.
3.4 Social Context of Cooperative Systems

Cooperative design is situated in social settings where distinct social norms and roles emerge, communication is both formal and informal, and design is often intermittent and unstructured. Informal communication tends to be brief, unplanned and frequent [Kraut90]. It supports both ongoing tasks as well as coordination of group activity and many social functions among participants. Steve Whittaker observed in studies of workplace communication [1994], “informal communications seem to consist of one long intermittent conversation consisting of multiple unplanned fragments often lacking openings and closings.” Whittaker had suggested the need for integrated shared workspaces for casual and asynchronous communication particularly for remote participants and support for exchange of documents (which were considered “conversational resources” and involved in over 53% of the workplace interactions). A key challenge in such informal communication was the need to “regenerate context” due to the time lags and intervening activity between the intermitted and unplanned interactions.

The ThinkCycle platform is designed to provide an online workspace for communication and archiving such intermittent dialogues about ongoing design projects, particularly with many distributed participants. The ThinkSpace tools are meant to provide an ongoing context for the temporal design activity. It is important to recognize the notions of “informal collaborative design” and consider how collaborative tools should support such modes of interaction. Informal collaborative design could be defined as ongoing, spontaneous and intermittent conversations and construction of design artifacts or supporting design rationale by many distributed, co-located or asynchronous participants. Open Collaborative Design builds on this notion by seeking to capture much of the formal and informal design activity such that a relevant portion of the artifacts, rationale and design process are made accessible in the public domain to participants other than just the design team involved.

How is informal design knowledge shared in different social and institutional settings? What is the incentive for people to participate in distributed settings? One way to answer some of these questions is to examine CSCW systems that try to capture organizational memory or facilitate sharing of knowledge/expertise. Two systems that have been used extensively include Answer Garden and Zephyr, both of which were studied by Mark Ackerman in online social settings.

3.4.1 Distributed Knowledge and Organizational Memory in CSCW

A class of systems broadly referred to as Computer-Supported Cooperative Work (CSCW), have tried to capture and provide access to distributed knowledge and organizational memory. In addition, some of these systems have considered the “social and technical affordances” necessary to promote ongoing activity, and not just initial adoption [Ackerman96]. We examine two such systems here and consider the lessons learned, as well as critical research issues for work in this thesis.

The Zephyr Help Instance at MIT [DellaFera98] is one of the best examples of a widely used CSCW system that facilitates distributed knowledge sharing for problem solving. It is a synchronous chat facility provided on MIT Athena workstations. Messages can be sent to individuals or to a shared channel (called “instance”) where multiple users are subscribed. Zephyr has a simple text-based user interface, allowing user to post messages easily and incoming messages pop up or scroll by on the screen. Though more sophisticated interfaces exist they are rarely used. The social usage of the system has been extensively studied [Ackerman96]; we will discuss some of the implications below. Though Zephyr provides an online means to access distributed knowledge, there is no notion of persistence or organization of such information for reuse and future access (this “memory-less” approach actually provides a lightweight interface for participants to use the system as a background task, as we will consider below).

Organizational memory is a record of an organization’s knowledge embodied in the individuals, culture, structure as well as internal and external archives of an organization. Though this
information persists in various forms within an organization, it is not easily accessible; information seeking requires knowledge of how to locate the right experts or sources as well as overcome social barriers related to status, prestige and reciprocity. Design rationale is a form of organizational memory, however previous systems like gIBIS [Conklin88] have not focused on informal information and flow of communication in the social network. In ThinkCycle, there is a desire to create an evolving collective memory from communities of practice, centered around collaborative design in problem domains of critical public interest. However, the nature of the problem domains requires capturing expertise across many diverse organizational settings.

Ackerman [1998] suggests the need for CSCW systems that support organizational memory by making recorded knowledge or the experts themselves accessible, in a manner that is centered on their current organizational activity. One such system, Answer Garden [Ackerman93] allows users to seek answers to commonly asked questions in an information database through sets of diagnostic questions (shown in menus or visual graphs) or through keyword search. However, Answer Garden also allows users to tap into the organization's social network by routing queries on unknown answers to appropriate human experts (via email). These experts may choose to answer the user directly as well as insert their answers (or their own diagnostic questions) directly into the database. This mechanism hence allows both users and experts to grow the body of information on the system over time, through a normal process of posing and answering questions. A field study of the system was performed at two different sites at MIT and Harvard [Ackerman98].

3.4.2 Understanding Social and Technical Affordances for Sustained Usage

Field studies are a crucial component of research in CSCW systems, to examine the actual usage and evolving adaptation of the system in its social and institutional context. Many of the lessons learned can be useful for design of future systems, though not necessarily generalized to apply to all. In particular it is more important to recognize the methods for studying such systems in practice and the types of issues revealed, for our approach towards ThinkCycle.

Field Study of CSCW Systems: Approaches and Outcomes

The fieldwork conducted by Mark Ackerman on both Zephyr and Answer Garden is instructive to examine. In the Zephyr study the focus was on users of the “Help Instance” discussion channel within Zephyr, consisting of mostly undergraduate students. There were over 500 users with a core group of 8% considered as “regulars”. Analysis consisted of qualitative examination of message logs for one semester (over 30,000 messages). In addition, 19 interviews were conducted with both heavy and lightweight users. Mark had also been a participant observer of the system for over 3 years. For the Answer Garden study, many field sites were used though two sites provided most of the data: a research group at MIT and a class at Harvard, with a total of 59 potential users. The focus on both these sites was on participants (mostly software engineers) using the X Windows system. Another set of participants was the experts who answered questions using the system, many of which had extensive experience in X Windows, and included the author. The study used many procedures to collect data including questionnaires, software usage data, participant observation, and interviews. A key mechanism was the “critical-incident interviews” which were short briefings with users typically shortly after their usage of the system. They were used to get users responses to specific incidents they encountered; 49 such interviews lasting 15-20 minutes were used in the study. There was an effort to combine the qualitative and quantitative data to gain better understanding in the field study.

Based on fieldwork in these CSCW systems we now consider a few of the social and technical affordances that encourage and sustain collaborative activity and shared contributions.

Shared Understanding of Social Roles: Social interaction in any situational context gradually establishes norms and roles that guide the behavior of participants in that setting. In CSCW systems like Zephyr and Answer Garden, roles such as “asker”, “answerer”, “expert” or “regular” emerge (with a range of attributes). A participant may move fluidly between roles or evolve to a
different role over time. A shared understanding of such roles is enforced by the design of the system and it in turn reinforces the consistent usage and expectations of participants.

Social Monitoring: Zephyr is not monitored or maintained by any central authority, but is rather sustained and organized by its users. Why does this work? “Social policing removes wildly deviant behavior on the Help Instance” [Ackerman96]. This is due to a system affordance that allows users to take a discussion to a different discussion channel. In addition, the overall tone of messages establishes a social protocol for the level of politeness expressed by users, and any sharp answers often bring corrective responses from other users online. The fact that all messages on Zephyr are highly public and visible also reinforces a self-correcting mechanism on the type of questions asked and the quality of answers provided.

Effects of Institutional Setting: Ackerman notes that, the organizational culture of MIT socially reinforces the intertwined roles of “asker” and “answerer” in the Zephyr system, through a perceived attribute of “cluefulness” i.e. a culture of providing and acknowledging technical expertise among peers. There is an implicit status implication or deference for “clueful” users (those who answer well) within such an institutional setting, which reinforces their active participation. This also affects “askers” who may be judged to be “clueless” unless they have searched other sources of information (like UNIX help pages) before asking naïve questions.

Status Implications in User Roles: In Answer Garden messages are sent to experts anonymously to reduce status implications with the users posting queries. This appeared to be beneficial for information seekers, however they still had hesitations in speaking directly with experts; here access to lower-level help desk personnel would reduce such status implications. It was found that experts too had status implications in their information-providing role. Users continued to “fret over their bothering the experts” – perhaps in regard to using their time. This suggested that a clear-cut distinction between experts and users was artificial and caused operational difficulties. Perhaps like Zephyr a more flexible set of roles, where users can act as experts and vise versa would have reduced such status implications.

Technical Affordances towards Participation: Both Zephyr and Answer Garden have simple interfaces, but still allow participants to “invoke a rich set of social behaviors and adaptations”. In Zephyr, the ability for a user to voluntarily attend to the messages as a background task or ignore them entirely, assists in sustaining continuous and long-term usage. The limited display and scroll-by nature of ongoing messages allows users to maintain lightweight participation in recent messages only, without having to immerse in longer-term context. Despite the simplicity of Zephyr, it provides means for distributed problem solving among users, in many cases with extensive iteration and negotiation to understand the problem and arrive at solutions. In Answer Garden both users and experts have distinct incentives towards using and contributing to the knowledgebase. The users are able to find answers quickly and experts rid themselves of commonly asked questions.
3.5 Design in Physical Context: Challenges for Distributed Collaboration

To what extent is product design tied to physical place in operational, social and cognitive ways? How should collaborative tools support both local and distributed modes of communication, cooperation and awareness in physical settings? In a study of social behavior in video-based collaborative systems at Xerox PARC, Harrison and Dourish [1996] recognize a distinction between “space” and “place” i.e. while space is a physical location it is often “invested with understandings of behavioral appropriateness, cultural expectations and so forth”; when one characterizes the practices of participants occupying the space, it is transformed into a “place”. This conceptual framework suggests that we must consider the role of “place” created in virtual settings and its coupling with spaces in the real world. To what extent should physical spaces be represented in virtual settings to provide effective social places for meaningful interaction? What are the unique characteristics of physical spaces that cannot be easily extended to virtual places, particularly with respect to cooperative design? Should online spaces augment existing design places or create new ones that span physical and institutional boundaries?

3.5.1 Awareness and Informal Communication among Co-located Designers

Most collaborative technologies are directed towards supporting distributed remote cooperation from user's desktops. Bellotti and Bly [1996] in a study of distributed product design teams highlight the role of informal design interactions in the social and physical settings of the workplace, and suggest the need to support both local collaboration and local mobility in product design. Their study shows that most members of design teams are rarely at their desks, and mobility is essential for their use of shared resources as well as informal communication and awareness of design activities in the workplace. They find that while local mobility enhances local collaboration, it severely puts long-distance distributed collaboration at a disadvantage. Distributed participants spend a great deal of time trying to gauge (usually unsuccessfully) whether relevant team members are available, when and where to find them and maintaining “common ground” through awareness of the state of ongoing design projects.

The study was conducted with a team of product designers distributed over several buildings of a design-consulting firm in Santa Clara and San Jose, California. The open office spaces included model shops, design offices and workspaces in different floors and buildings. Most designers in this professional engineering setting used computers extensively for 3D CAD designs, and only preliminary sketches were done on paper. However, despite dedicated T1 lines and networked infrastructure, the industrial designers communicated with model makers by physically taking their sketches and drawings to the model shops, while design work was shared across buildings via fax. No explicit “groupware” products were used, besides email, phones and faxes. The study was conducted using interviews, attending design meetings, and close observation of selected engineers and designers.

In most cases, design engineers spent less than 10-15% of their time at their desks. Observation of daily activities of team members revealed that two main motivations behind increased local mobility: 1) they often used shared resources not available in their own offices, and they frequently had a desire to communicate and be aware of design activities in the workplace. They found that design work involved a range of means to articulate and evaluate evolving concepts including drawings (on different media), related work (documents), building models and awareness of ongoing projects. Hence different modes and artifacts of the design process required frequent usage of different resources such as scanners, printers, CAD workstations, model shops and engineering labs. Engineers often wandered about the various design offices or labs within and across buildings primarily to meet others for face-to-face discussions and informal awareness of design activities. Their time spent on desktop PCs was minimal compared to local mobility for awareness and face-to-face encounters. One engineer referred to this wandering as doing a “walkabout” - apparently to gain useful information passively through informal conversations and observations of others work. “Awareness of someone’s current work focus provided an entry into topic of mutual concern… allowing people to solicit or spontaneously offer
feedback on designs”. Hence the close physical proximity and regular “walkabouts” greatly facilitated awareness, communication, learning and personal experience with ongoing projects.

Bellotti and Bly suggest that this phenomenon of local mobility presents many problems as well as opportunities for design of technologies for distributed collaboration. While passive mutual awareness of co-located team members provides many benefits, distributed collaborators cannot easily establish the appropriate context and familiarity for timely, spontaneous and informal interactions. Communication and coordination was often preferred face-to-face over the phone or email. Mutual awareness and co-presence greatly facilitated these tasks. Hence collaborative tools must support mechanisms for social awareness as well as means to make the ongoing design process more visible. This can be accomplished to some extent by making capture and online representation of ongoing design work easier, as well as providing opportunities for distributed participants to communicate informally and spontaneously. General video conferencing and file sharing tools tend to be structured as formal activities, rather than the peripheral, fluid and casual mechanisms expected in co-located settings. How should collaborative systems be designed to allow distributed team members to “hang out” informally, and implicitly share and maintain awareness of ongoing design projects? To what extent should synchronous or asynchronous forms of cooperation and communication be supported? How should collaboration and design awareness be supported “away from the desktop”? This study suggests the need for a variety of novel collaboration tools and practices that emphasize informal, lightweight and asynchronous modalities of usage on both desktop and mobile platforms.

3.5.2 Nature of Creative Design Shaped by Physical Settings of the Workplace

Most computer-supported collaboration systems have been developed for product engineering design. They are generally designed to match the perceived structure of the engineering process, though as we have seen in the study by Bellotti and Bly that informal practices of awareness and communication are critical even in engineering settings. There has been less focus on the creative and unstructured individual/cooperative design activity in such settings.

Creative product design is considered a cooperative activity involving client interaction, collaboration and peer learning among junior, senior and “master” designers, as well as interdisciplinary contributions from other specialized designers, engineers, marketing and production experts. Few studies on the social, physical and cooperative nature of creative design have been conducted, particularly in the context of developing tools and environments that better support collaborative design. Levia-Lobos [1997] and Michelis [2000] at the University of Milano, describe ethnographic studies of industrial design settings conducted at the Domus Academy Research Center (a prominent design school in Italy). The Milano group’s fieldwork involved understanding the spatial setting of the design workplace, cooperative relations among team members as well as clients, and the manner in which designers used tools and structured work practices.

The study indicated that the physical setting of the Domus Academy played a key role in “shaping the work style” of the designers. The space supported a natural means for sharing knowledge created on a daily basis while the proximity of team members encouraged a “very sensitive type of collaboration” among them. However, the physical nature of design coupled with the distance from clients and high mobility of the “master designers” (who were frequently away from the design center) often created “breakdowns in project development”.

The researchers describe the physical setting of the Domus Academy as an open design laboratory with workspaces for team projects and shared intersection areas for common resources (such as workstations and office tools). In contrast to the engineers in San Jose studied by Bellotti and Bly, who heavily relied on CAD systems, the Milano researchers found the role of computers in the laboratory to be “limited to peripheral activities in the creative process” such as writing documents, editing images, using email and searching the web. They found that designers at this center in general avoided the “(hyper-)realism of rendering systems” preferring to do handmade sketches and models. Project workspaces were observed to be highly “decorated” with illustrative designs and artifacts both used and emerging from the ongoing
production work. Such artifacts included design magazines, materials for sketching and modeling, project files and drawings, production tools, project work-plans and matrices, annotated visual artifacts, and communication devices (phones, fax, cameras, networked PCs etc). This large variety of artifacts and intermediate outcomes support the researchers arguments on the primacy of physical design - “physical dimension of designers’ work space cannot be substitutable by a pure electronic space… the design activity itself appears highly physical to an outside observer; while working designers continuously touch the objects, draw by hand, move things with respect to light sources, etc”. The researchers feel that “newly conceived computer-based tools should not aim to substitute the existing ‘mechanical’ tools but merely to augment their effectiveness”.

The researchers conducted a closer examination of the development process of a client design project between the Domus Academy and an Italian manufacturer, focusing on control devices for smart homes. Though their findings are highly specific to the design process observed, further discussions with designers provided a basis for posing somewhat generalized outcomes:

- **Multiplicity of Workspaces**: The researchers found that the design process does not occur within any single workspace but within a “system of interrelated workspaces whose quality depends on the facility with which the designer may switch among them”. The manner in which the client design project was conducted in the field study lead to a perception that there were two workspaces in the design process – “the creative workspace populated only by the designers” where ideas were internally generated and evaluated with master designers (who acted as clients) and the “customer-performer workspace” where the teams interacted with customers and the master designer takes on the role of performer guiding the exhibition of the team’s work. This sharp distinction in boundaries of the two workspaces may have been implicitly setup to protect the freedom of designers form interference from clients, while the absence of more frequent interaction also lead to breakdowns in communicating ideas effectively between both parties. During such design projects the product requirements do not remain fixed but are continually negotiated while both designers and clients continue to create new knowledge on the problem being addressed. While there is much interaction with clients in the early stages of a project, lack of communication in the design process causes many more design iterations and potential misunderstandings. The researchers suggest that setting up virtual “customer-performer workspaces” may provide a “limited and controlled window on the creative workspace” better coupling the design process with client expectations.

- **Continuous Learning and Knowledge Creation**: The process of production and creation appears to be one that requires ongoing interaction, knowledge exchange, listening, understanding, drawing, constructing, visualizing and so on among designers as well as clients. The different forms of social interaction greatly facilitate both the process of learning and the transformation of explicit knowledge into product design. Junior designers learn the Academy’s style and practice through peripheral interaction with ongoing projects stimulated by master designers. Ideas are often developed in both formal and informal meetings with clients and visitors. Through team projects and “cross fertilization designers improve their professional capabilities for explaining, sharing and revising design ideas with each other.” Hence it seems essential to support this ongoing process of learning and knowledge exchange through peripheral participation and awareness of ongoing design projects and explicit opportunities for sharing, peer-review and presentation with designers, clients and visitors.

- **Situated Context and Cognition**: The study indicates that the “physical arrangement of the workspace makes the historical and spatial context of the project visible to its participants.” This situated context is clearly not retained in electronic representations or collaborative systems. The researchers assert that rather than trying to replicate this context electronically, some relevant aspects should be captured to allow remote participants to an awareness of the relevant context. In addition, many workspaces such as the “customer-performer workspace” are only temporarily created in the physical
space, hence some permanent virtual extension of such ad-hoc workspaces, if captured, would support coherent awareness of the context.

I feel that this study of creative design in physical settings suggests several criteria for collaborative systems, that better support physical and situated design among distributed participants: 1) showing a history of ongoing communication and formal/informal design artifacts created over time, 2) allowing continuity to support smooth transitions between synchronous and asynchronous modes of interaction, 3) social awareness of participants and concurrent design in cooperative projects, 4) sustaining distinct representations of workspaces (for teams vs. clients) while permitting exchange of mutually relevant content, 5) supporting unstructured phases of creative design through the lifecycle of a product, 6) supporting project awareness and peer-review by both clients and master designers who play a key role in the design process, and finally 7) recognizing the clear limitations of virtual spaces to support all aspects of physical settings, and hence managing expectations for design and usage of such collaborative systems.

Michelis emphasizes the need for this kind of “weak augmentation” of design settings, relative to many “heavyweight” augmented reality systems proposed for physical design environments. Hence, collaborative systems for design interaction among distributed communities should at best facilitate the creation of Weakly Augmented Places that support social awareness, informal communication and multiple representations of evolving and weakly structured design processes.

**Summary: Rationale, Social and Physical Context in the Design Process**

Studies and experiences from ongoing design projects reveal several key social issues and challenges that emerge in such collaborative online design settings. Most of these issues were also observed in early usage among members of the ThinkCycle community and are certainly relevant as the system is more widely used and adopted in the future.

- **Design Rationale** is difficult to capture from participants engaged in product design, as much of it is conducted in face-to-face physical settings, and there does not usually exist strong practice or incentives for documenting ongoing design iterations. Hence, instead of enforcing structured interaction and formal capture, online system should strive to extract rationale and dependencies in the form of informal dialogue, weak explanations, and context from existing design artifacts, online resources and ongoing user interaction. The outcomes of a design process should be considered an unfinished document and an evolving group memory, which can be searched, associated and continually expanded.

- **Social Norms** naturally emerge and continually evolve in online cooperative systems, as a function of their inherent social and technical affordances. To support sustained and productive interaction, such system must allow opportunities for informal and unplanned interaction, lightweight mechanisms for users to maintain awareness and contribute to the design process, and ability for users to adopt a range of direct or peripheral roles on the system over time. Shared understanding of such affordances and roles reinforces consistent usage and expectations of participants in online settings. Social protocols, conventions and monitoring mechanisms are negotiated among users over time. The affordances or limitations of the interface invoke a rich set of behaviors and adaptations.

- **Physical Context**: The nature of creative design is shaped by the physical environment and spontaneous interaction among co-located participants. The physical setting influences the workstyle of designers and physical proximity provides many implicit means (through walkabouts and informal dialogue) for sharing knowledge and gaining feedback within the community. Much of the design activity in engineering/design settings does not usually occur on the desktop, while local mobility and interaction serve an important role. Online collaboration platforms can augment such design interactions by capturing evolving knowledge and context, and allowing remote participants to engage in the design process. Online systems should provide greater support for social awareness, multiple representations, as well as peripheral and asynchronous modes of interaction.