Cooperative Innovation in the Commons:
Rethinking Distributed Collaboration and Intellectual Property for Sustainable Design Innovation

by

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SUBMITTED TO THE PROGRAM IN MEDIA ARTS & SCIENCES, SCHOOL OF ARCHITECTURE & PLANNING, IN PARTIAL FULLFILLMENT OF THE REQUIREMENTS OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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ABSTRACT

Addressing global design challenges in the environment and underserved communities requires a cooperative approach towards sustainable design innovation, one that embraces multidisciplinary expertise, participatory design and rapid dissemination of critical innovations in the field. How can a rural farmer in Botswana cooperatively develop appropriate solutions for his community with external research expertise? How can a doctor in Sao Paulo access a network of medical device companies to help manufacture her design innovation? While there is a great emphasis on large breakthrough R&D innovations, there is often little support for developing and disseminating small-scale, affordable, and locally sustainable designs.

The open source phenomenon has been influential in the software community, however distributed collaboration in engineering design requires awareness and sharing of physical artifacts, design tools and working environments as well as novel mechanisms to support social norms, communities of practice, and intellectual property rights for product innovations. ThinkCycle was created as a web-based collaboration platform with tools and shared online spaces for designers, domain experts and stakeholders to discuss, develop and peer-review evolving design solutions in critical domains. Over 2000 users worldwide access and contribute hundreds of concepts, resources, projects and publications on the site. ThinkCycle is emerging as a collaborative platform, open design repository and global community for innovations in sustainable design: *http://www.thinkcycle.org*.

Studies were conducted on the nature of design interaction, learning and intellectual property emerging from studio courses run at MIT in 2001-2002. Cooperative design is best understood when viewed as a "social process", which is better sustained in online settings by peer-review from remote participants. There is a need for lightweight asynchronous interfaces with existing modes of communication like email. Social inquiry into notions of intellectual property reveal a typology of patterns with distinct forms of protection and disclosure, including patents and open source, adopted under different conditions. However, there is much ambiguity and conflict regarding how to deal with cooperative innovations as they evolve from being subpatentable learning experiments to functional and commercially viable solutions with potentially great social impact. The thesis provides a framework within which we can begin to explore these challenges.

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1 INTRODUCTION: COOPERATIVE INNOVATION IN THE COMMONS?

How should we create an environment that supports global interdisciplinary cooperation towards open design innovation in critical problem domains? This introduction begins with a strong argument for expanding the scope of cooperative R&D towards sustainable design innovation that supports, what I consider, *Universal Human Rights*. Lessons from the *Appropriate Technology* movement suggest the need for local and global cooperation in taking design innovations from concept to market, engaging a broader academic/research community and developing novel models for dealing with intellectual property rights. These three issues remain the core challenges and themes for the thesis: *Cooperation, Community* and *Intellectual Property*.

Several global trends in the last decade including networked computing, increasing interest in sustainable development, emergence of the open source movement and rethinking of the "commons", present new conditions today for innovative approaches to solve problems. I believe the convergence of these trends led to the emergence of the *ThinkCycle* initiative for *Open Collaborative Design* at MIT, which I co-founded and use as a basis for this thesis work. I describe the primary vision and related initiatives, including the *Design that Matters* studio courses, *development by design* conferences and the online collaboration platform. The latter is the primary focus of the thesis, with an exploration of the technical and social challenges involved in developing the collaboration system, examination of its usage by students in studio design courses and the intellectual property issues emerging as a result of the cooperative design outcomes. I conclude the introduction by outlining the key research challenges for this thesis and summarizing the main chapters that follow.

1.1 Supporting Cooperative R&D to Ensure Universal Human Rights

The growing social and environmental impact of current industrial practices and inequity in the everyday lives of the underprivileged, creates a critical condition today for radical and innovative approaches towards sustainable development and design. Developmental economists Amartya Sen and Jean Dreze [1995] have pointed out that the central feature in the process of development should be the *"expansion of human capabilities and freedoms"*. In their studies in developing countries they have often observed that gains from economic growth are not always channeled into remedying the deprivations of the most needy or necessarily creating employment or social opportunities for all. Their economic theories have been adopted in recent developmental studies by organizations such as the United Nations Development Program (UNDP). The UNDP releases its Human Development Report[1] (HDR) each year, examining the comparative indicators of development in countries around the world as measured by the Human Development Index (HDI). These studies often demonstrate that despite similar income levels reported among many developing countries, factors such as life expectancy and adult literacy remain dramatically different (see figure 1.1). Hence, economic growth alone clearly does not assure human development, equitable access, rights and freedom among all citizens worldwide.

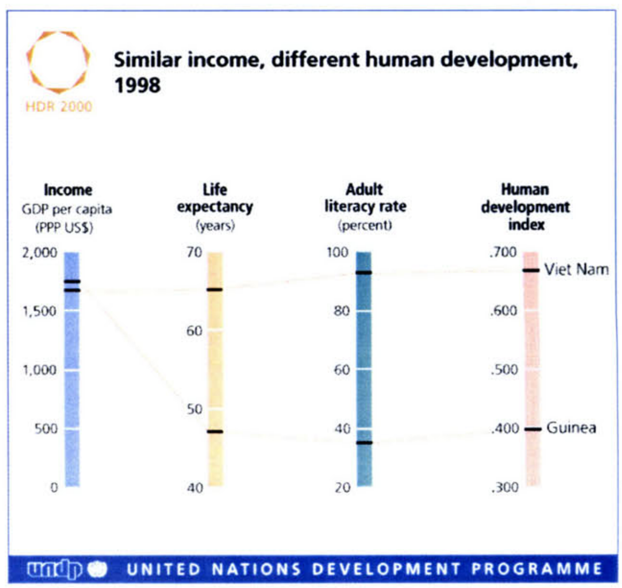

Figure 1.1: This figure from the United Nations Development Program (UNDP) Human Development Report 2000 demonstrates that while two countries such as Vietnam and Guinea may have similar income levels (GDP), the rate of life expectancy and adult literacy may be dramatically different, leading to different levels of human development.

[1] http://hdr.undp.org/

In my opinion expanding human capabilities and freedoms as Amartya Sen proposes, requires a conscious developmental approach that provides greater access to what I believe should be *Universal Human Rights*[2], such as clean water, clean air, affordable healthcare, primary education and political participation. These universal human rights can only be addressed effectively if we approach them with values that promote individual aspirations, equity, participation, better environment and socio-economic sustainability. In addition to broad community and developmental programs, I believe that ongoing research and practice towards *Sustainable Design Innovation* has a strong role to play in making such outcomes attainable in an appropriate and socially relevant manner. Hence, I feel that there is an urgent mandate today to expand the nature and scope of cooperative R&D among academia, industry, government, the nonprofit sector and grassroots innovators worldwide to better address Universal Human Rights.

One way to approach research and design in critical problem domains is by taking advantage of the unique experiences and expertise of individuals in diverse institutions and localized settings. Innovation may emerge by a nexus of individual and cooperative efforts, while distribution and access requires yet another range of mechanisms and channels. How do we ensure that there is sufficient awareness and dialogue among stakeholders, domain experts, researchers and field-organizations to make the design process participatory, the emerging concepts open to peer-review, and the outcomes sustainable and accessible to all? Under what conditions is cooperative design an appropriate means for approaching such challenges? How do we support distributed collaboration, peer-review, learning and dissemination among diverse participants worldwide? What systems, principles and design approaches support sustainable development and design? I now draw upon experiences and lessons from the Appropriate Technology movement and recent global trends, before describing the nature and emergence of the ThinkCycle initiative.

1.2 Papanek and Schumacher's Vision and the Appropriate Technology Movement

The *Appropriate Technology* movement was initiated in the 1970's, inspired by the pioneering work of visionaries like E. F. Schumacher and Victor Papanek. E. F. Schumacher's seminal book "Small is Beautiful" [1973] provided a critique of the problems of Western economics and outlined his approach towards human-scale, decentralized, and appropriate technologies. Schumacher suggested that the current manner in which society pursued profit and progress promoted large organizations and increased specialization, leading to gross economic inefficiency, environmental pollution, and inhumane working conditions. He proposed a system of "Intermediate Technology" based on smaller working units, co-operative ownership, and regional workplaces using local labor and resources. He believed that ultimately products and capital should serve people rather than the converse, which was more prevalent at the time. His philosophy was often characterized as "economics from the heart rather than from the bottom line". Schumacher's book, which sold over 700,000 copies in multiple languages, had a tremendous influence on shaping ideas about self-sufficiency and commonsense economics for many generations.

Victor Papanek has always been a strong advocate for socially responsible design of products and processes. In his book "Design for the Real World", first published in 1969, he challenged industrial designers and industry to rethink existing design practices within the appropriate social, economic and environmental context, and reconsider their moral responsibility towards human-centered human-scale design. He believed that "the only important thing about design is how it relates to people." Papanek had a strong background in anthropology as well as in architecture and product design. Papanek traveled around the world giving lecture about his ideas for ecologically sound design and designs to serve the poor, the disabled and the elderly. Papanek created products for UNESCO and the World Health Organization, and provided consultation to the governments of Nigeria, Tanzania, and Papua New Guinea. His declarations on the role of

[2] This terminology should not be confused with the *Universal Declaration of Human Rights* adopted by member states of the United Nations, in a resolution of the General Assembly on December 10, 1948. *Universal Human Rights* is a term I use to refer to universally applicable environmental and socio-economic capabilities, rights and freedoms for all individuals that goes beyond the typical Human Rights mandate. In this thesis, the notion of Universal Human Rights serves to motivate an urgent expansion of cooperative R&D initiatives in sustainable technology and design. However, one must recognize that this notion of a "universal" set of human rights in different cultural contexts must be carefully considered.

design in the modern era were based on well-considered explorations into the relationships between people and their tools, particularly among indigenous communities. Papanek believed that design should be "operative" throughout its value chain, i.e. in terms of how the entire process of design to manufacture to distribution is conceptualized in a manner that is socially and environmentally appropriate (using local resources and tools for example). In teaching design he wished to establish "design communes" where there could be greater peer learning across multiple disciplines. He felt that rather than exporting design and products to developing countries, local capacities should be developed by promoting indigenous designers through cooperative seed projects with western designers. Finally, Papanek also felt it was unethical to keep socially valuable design ideas protected, and discouraged patents in such areas.

Many of these principles of socially relevant design, local resources and manufacture, and the ethical spirit of disseminating design innovations were widely adopted by individuals and organizations working in developing countries, that came to be part of the so-called Appropriate Technology (AT) movement. While many design innovations emerged from this movement, it was not influential enough among industry and practitioners to successfully bring these innovations to market. Many feel that the AT movement declined due to a prioritizing of ideological principles over understanding of user needs and market dynamics [Donaldson2002]. For example, "decentralized production" which may have been a worthwhile goal would have been less cost effective or suitable in many areas with poor manufacturing capabilities and existing distribution networks. I summarize here three broad challenges within the Appropriate Technology movement, which I believe can be tackled differently today.

- *Seeking Local and Global Cooperation in Design to Market:* While design innovations may emerge in localized settings, there is a need to work closely with local and global partners in industry, government and the nonprofit sector to ensure production, distribution and deployment of products from concept to market. Many viable designs were never fully produced due to lack of funds and facilities to design, prototype and manufacture a product or dealing with regulations. Many innovations manufactured were not properly promoted, distributed or packaged as consumer products. While the AT movement rejected market-based values and practices, this led to an ignorance of sustainable business models, infrastructure needs, recognition of the complexities of the product lifecycle and the inherent forward/backward linkages over time. Hence, there is a need to support cooperation among diverse entities for venture funding, manufacture, distribution, testing, and marketing to ensure design concepts can be translated into successful consumer products and services operating throughout the value chain.

- *Engaging a Multidisciplinary Intellectual Community:* There has been a lack of engagement by practitioners with the academic and research community to conceptualize, review and rigorously test and evaluate ongoing design solutions. Specialized domain expertise and resources in critical areas can help in the design process, feasibility analysis, evaluation and implementation, particularly for complex products and processes. Novel techniques and materials can provide affordable and appropriate options not considered in field settings. While many AT innovations were sometimes documented in how-to manuals, they were rarely published in academic conferences or journals. Hence there was a lack of communication with researchers and lack of legitimacy given to these locally developed designs and practices, leading to poor dissemination, evaluation and adoption in the mainstream. Lessons learned and failures reported provide valuable insights for future work. Cross-pollination is needed among multi-disciplinary researchers and practitioners both at local scales and global networks.

- *Rethinking Intellectual Property Rights to Ensure Production and Dissemination:* Most AT innovations have generally been subsidized and disseminated freely through how-to publications, however that has given little incentive to manufacturers for producing commercially viable products. One needs to consider what form of protection and licensing is appropriate for different kinds of innovations, such that grassroots invention is rewarded while useful innovations are manufactured and made widely available.

While many new initiatives continue to emerge today such as *Green Design*, *Eco-Efficiency* and *Sustainable Design*, with somewhat revised principles and ideologies, I believe that the critical challenges outlined above need to be carefully addressed to ensure successful outcomes.

1.3 Revisiting Vannevar Bush's Memex: Leveraging Emerging Global Trends Today

What if Schumacher and Papanek had met Vannevar Bush, would the Appropriate Technology movement have been more influential? Vannevar Bush a former MIT president and Director of the wartime Office of Scientific Research and Development wrote an article "As We May Think" in the Atlantic Monthly in 1945. In his article Bush urged scientists to turn their energies from war to the task of making the vast store of human knowledge accessible and useful. He also described a concept for a device he called the "Memex", which operated not much unlike the Internet today:

> *"Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and, to coin one at random, "memex" will do. A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory… If the user wishes to consult a certain book, he taps its code on the keyboard, and the title page of the book promptly appears before him, projected onto one of his viewing positions… It affords an immediate step, however, to associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the Memex… Moreover, when numerous items have been thus joined together to form a trail, they can be reviewed in turn, rapidly or slowly, by deflecting a lever like that used for turning the pages of a book. It is exactly as though the physical items had been gathered together from widely separated sources and bound together to form a new book."*
>
> Bush goes on to say, *"Wholly new forms of encyclopedias will appear, ready made with a mesh of associative trails running through them, ready to be dropped into the memex and there amplified. The lawyer has at his touch the associated opinions and decisions of his whole experience, and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case, and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds, and side trails to their physical and chemical behavior."*

Bush's vision was a kind of precursor to the networked technologies of the Internet and far more. He predicted random access, association (linking), commenting, capturing, search and so on. Much of the Internet still remains a one-way broadcast medium, however with personalized and collaborative technologies it is beginning to be transformed into a true "memex". Perhaps if Schumacher and Papanek had known about the memex, they might have considered a means to expand their vision to interconnected evolving knowledge thriving from a networked global community. In his article Bush remarked, "Science may implement the ways in which man produces, stores and consults the record of his race." I believe this convergence of critical ideas from Schumacher, Papanek and Bush shaped the nature of the ThinkCycle initiative. Three global trends emerging in the 1980's and 90's provide what I feel are unique conditions today for novel approaches to the key challenges of Appropriate Technology mentioned earlier:

- Emergence of Distributed Online Communities and Networked Computing
- Increasing Global Dialogue on the "Digital Divide" and "Sustainable Development"
- Bold New Movements around Intellectual Property in the Public Domain

These ongoing trends (discussed in more detail in chapters 2 and 3 of this thesis), which implicitly highlight the key issues of *cooperation, community and intellectual property*, I believe led to the emergence of the ThinkCycle initiative at MIT in 2000-2002.

1.4 ThinkCycle: A Cooperative Culture of Socially-Conscious Design Innovation

How does one design better water filters for the 1.7 billion people lacking access to clean water, simplified IV treatment devices for cholera patients in refugee camps, low-cost prescription eye-wear for communities in Africa or temporary shelters for disaster relief? How can a rural farmer in Botswana work with students and domain experts in universities like MIT to cooperatively develop appropriate solutions for his or her community? How can a doctor in Sao Paulo gain access to a network of medical device companies to help manufacture and disseminate his design innovations widely? While there is a great emphasis on large breakthrough R&D innovations, there is often little support for developing and disseminating small-scale, affordable and locally sustainable designs, which have impact in critical areas. In my view, it is possible to use networked technologies and distributed collaboration to improve the way existing market mechanisms, academia and government organizations address critical design challenges in underserved communities and the environment.

1.4.1 Open Source and Distributed Collaboration

The networked medium of the Internet lowers the technical barriers for distributed collaboration, however there are many challenges for sustaining cooperative social enterprise towards product innovation across institutional boundaries. Recent trends in the "open source" movement suggest that many benefits can be derived from sharing design knowledge, and allowing an "open" evolution of design based on public peer-review and contributions from diverse participants. Eric Raymond [1997], in an article[3] characterizing the evolution of open source software like Linux, pointed out the importance of a large base of distributed users who help improve the design outcomes much more rapidly but also become indispensable co-developers, if "properly cultivated" during the design process.

This "Bazaar view" of software development relies on the fact that each co-developer due to their unique background and interests, views the problem with a "slightly different perceptual set and analytical toolkit". This approach is particularly valuable in complex problem domains where expertise cannot easily be found in any one institutional setting, and a wider design exploration of many simultaneous design alternatives and approaches is necessary. How should one support open source collaboration for sustainable design challenges in product engineering? Is it an appropriate approach in product innovation? While the open source phenomenon has been influential in the software community, distributed collaboration in knowledge-intensive engineering design requires widely accessible online design tools as well as novel mechanisms for supporting field deployment, intellectual property rights and product commercialization. In chapter 2 of this thesis I will re-examine the open source methodology in the context of both software and product design, and consider the challenges for transferring this notion of peer production to the design domains.

I believe that there is a genuine need for developing novel collaborative platforms while creating a culture of sustainable design innovation among institutions around such problem domains. Over a period of three years since 2000, I helped establish *ThinkCycle*[4] as an MIT-wide initiative, which seeks to support *Open Collaborative Design* for sustainable solutions to challenges in the environment and underserved communities, with active participation of universities and organizations worldwide. In this thesis, I undertake a closer examination of these assumptions by evaluating the role of collaboration, learning and intellectual property rights for sustainable design initiatives.

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[3] http://www.tuxedo.org/~esr/writings/cathedral-bazaar/cathedral-bazaar/

[4] http://www.thinkcycle.org

1.4.2 *ThinkCycle and Design that Matters: A Brief History*

In March 2000, along with several graduate students at the MIT Media Lab, I proposed *ThinkCycle* as an initiative to enable "open source problem solving" among university students everywhere and underserved communities. A key part of the initiative was to create an online database of well-posed problems and evolving design solutions. This would be designed to facilitate exchange, raise awareness and harness the expertise of students towards real-world and appropriate design of technology for their communities and the environment. However, it became clear that we first needed to encourage a culture of socially conscious design in the university.

Figure 1.2: The ThinkCycle logo symbolizing *Open Collaborative Design* among industry, academia and nonprofit partners. The logo was designed by Wendy Plesniak.

In February 2001, in consultation with Media Lab professor Mitchel Resnick, we initiated a pilot design studio course at MIT appropriately titled "Design that Matters"[5], as a novel experiment to devise a pedagogical approach that would seed challenges and design solutions for the initiative. The goal of the studio course was for students to solve "real-world" design challenges posed by non-governmental organizations (NGOs) working in underserved communities. The studio brought together students from across MIT and Harvard, with notable speakers from around the world to focus on problems like access to clean water, human generated power, bilingual language learning, low-cost health treatment and adaptive eyewear. Student teams built working prototypes with peer review from domain experts and documented their evolving designs using an experimental online collaboration platform. This studio was conducted at the MIT Media Lab in spring 2002, producing several award winning design outcomes[6] such as a passive incubators for infants in Sri Lanka and ceramic/bio-sand household water treatment systems in Nicaragua.

In April 2001, I began development of the ThinkCycle online collaboration system built on top of an Oracle database and web-based platform. The system was iteratively designed with feedback from students in the course. An early version of the site was introduced in May 2001 for students to use in documenting their projects online. Over 16 months of development, the system has been extended with many collaborative features and performance improvements to make it a robust and usable online design platform. The system architecture, design and development is described in detail in chapter 3 of this thesis. As of January 2003, ThinkCycle has been used by over 2000 individuals in universities and organizations worldwide, to browse and contribute hundreds of design content/resources in over 45 critical topic domains. ThinkCycle continues to grow as a distributed community and open public domain site to support ongoing cooperative efforts, peer review and global dissemination of innovative ideas in sustainable design.

1.4.3 *"development by design": Towards a Global Design Network*

On the heels of the ThinkCycle initiative, I co-organized an international workshop at MIT called *development by design*[7] (dyd01) in July 2001, which brought together experts in developmental innovation and sustainable design from all around the world. This was established as a peer-reviewed workshop with technical papers submitted online by all participants in diverse domains of interest, ranging from design of appropriate technologies, novel educational models, environmental solutions, open source innovation in rural settings, low-cost mobile/internet technology and so on. All papers were submitted, peer-reviewed and archived in a digital publication library developed on ThinkCycle. With over 100 participants from US, Europe and developing countries such as India, Brazil, Kenya and Nepal, the workshop provided a unique forum for a critical discourse on sustainable design and technology.

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[5] http://www.media.mit.edu/~nitin/thinkcycle/
[6] http://www.mit.edu/~ideas/winners.html
[7] http://www.thinkcycle.org/dyd

The 2nd event, *development by design 2002*[8] (dyd02), was established as an international conference in Bangalore, India, December 1-2, 2002, in conjunction with Media Lab Asia, the MIT Alliance for Global Sustainability (AGS), Indian Institute of Sciences and Srishti Schools of Art, Technology and Design. It was held in cooperation with the ACM SIGCHI, ICSID, Infosys Technologies and Concept Labs. I served as the program co-chair for the conference, ensuring that we could develop a strong and compelling technical program. Over 120 papers were submitted and peer reviewed online on ThinkCycle, by an international program committee as well as the general public.

International Conference on Open Collaborative Design for Sustainable Innovation, Bangalore, India. December 1-2, 2002.

Figure 1.3: The logo for the 2nd international "development by design" conference. The logo was designed by Surabhi Prasanna in Bangalore.

Nearly 200-300 participants from around the world attended the conference in Bangalore, along with invited experts and panelists. The 3-day event included pre-conference workshops, panel and paper sessions as well as informal participative events. Printed proceedings for the conference will be released in 2003 with selected papers, workshop summaries and thematic editorials. The next dyd conference will be held in Sao Paulo, Brazil in 2004. Hence the conferences continue to expand to develop a community of interest among academia, industry and the nonprofit sector. I believe such forums are critical to maintain genuine interest and establish greater legitimacy for design innovation in emerging areas of research and practice.

Both the *Design that Matters* studio course and dyd events have both emphasized that the critical challenges of sustainable development and the environment must continue to be addressed by meaningful collaboration among various institutions. Expanding the pedagogical emphasis for sustainable design is critical among universities everywhere. In 2002 we encouraged faculty and students at several universities around the world to develop similar design studios, run in conjunction with the MIT Design Studio. Faculty in Bangalore, Lisbon, Sao Paulo and Nairobi proposed to conduct their own Design that Matters courses. Each studio would be run in a unique manner with participation of local organizations and potential collaboration among the schools. The following initiatives were setup as part of the *Global Design Network*[9] in 2002:

- *Design that Matters (DtM02)*[10]*, Cambridge, USA*
  Massachusetts Institute of Technology
- *Learning from Grassroots Innovators*[11]*, Bangalore, India*
  Srishti School of Art, Design & Technology, Indian Institute of Sciences (IISC), and National Innovation Foundation
- *Collaborative Design Studios*[12]*, Lisbon, Portugal*
  GASA-FCT-UNL, New University of Lisbon and IST, Technical University of Lisbon
- *Engineering Design for Development*[13]*, Nairobi, Kenya*
  University of Nairobi with Numerical Machining Complex (NMC) Ltd.
- *Social Design Studio*[14]*, Sao Paulo, Brazil*
  University of Sao Paulo with network of local organizations
- *ThinkCycle Student Initiative*[15]*, Pittsburgh, USA*
  University of Pittsburgh and Carnegie Mellon University

[8] http://www.thinkcycle.org/dyd02
[9] http://www.thinkcycle.org/global-dtm
[10] http://www.thinkcycle.org/dtm
[11] http://cpdm.iisc.ernet.in/dtm.htm
[12] http://gasa.dcea.fct.unl.pt/thinkcycle/index2.asp
[13] http://www.thinkcycle.org/global-dtm/edd_abstract.pdf
[14] http://www.cidade.usp.br/sds/
[15] http://www.pitt.edu/~mab77/tcyclepgh.htm

Of these initiatives, the studio courses at MIT and Bangalore were formally conducted in 2002. The design studios conducted at MIT in 2001 and 2002 have been evaluated (described in chapter 4), along with learning outcomes and usage patterns of the ThinkCycle platform.

1.5 Thesis Research: Cooperation, Community and Intellectual Property

The key research challenges for this thesis work can be summarized as follows:

A. ***Architectures for Distributed Cooperation:*** What is the role of online collaborative platforms for distributed design and problem solving in critical domains? How should a online platform be developed to support diverse geographically dispersed communities, with distinct cultural and social norms or varying levels of bandwidth and connectivity? How can a platform be structured to deal with diverse problem domains and communities of interest, and made robust and scaleable for thousands of participants worldwide? It has been challenge to develop a comprehensive online system and design appropriate interaction mechanisms for distributed collaboration. In chapter 2, I describe the rationale for considering distributed collaboration and the open source approach, as well as the potential limitations. In chapter 3, I describe the design evolution of the ThinkCycle platform and closely examine the technical and social challenges for developing and sustaining it. In chapter 4, I examine the nature of online design collaboration, usage patterns and social issues emerging on ThinkCycle, based on a study I conducted.

B. ***Supporting Communities of Practice:*** While an online system and collaborative tools provides the "infrastructure" for cooperation, productive social interaction emerges when the appropriate incentives, norms and conditions are in place. What are the social and technical conditions that support distributed communities? What is the nature of social interaction in online settings like ThinkCycle? Do participants interact as a unified "community" or diverse "social collectives" with distinct and often conflicting interests? How do communities of practice in physical settings differ from those emerging online? What is the nature of social incentives and peer learning in online cooperative design? I examine these questions in chapters 2 and 3, while discussing the open source movement and existing online communities. I also examine the nature of community interaction and social norms emerging on ThinkCycle in chapters 3 and 4, based on my experience developing the online platform and from surveys and interviews conducted.

C. ***Rethinking Intellectual Property Rights:*** The outcomes of individual or cooperative design may yield intellectual contributions that are beneficial to disseminate. During two years of studio projects and online interactions on ThinkCycle, several design innovations have been documented and continue to evolve with ongoing peer review. What is the manner in which participants deal with their intellectual property rights (IPR) in terms of sharing, protection and dissemination of individual or cooperative efforts? Under what conditions do innovators adopt open source, patents, public or proprietary disclosure of ongoing designs? What social incentives and online mechanisms support diverse forms of IPR solutions? I examine prior work on IPR in chapter 2 and discuss results from a sociological inquiry with participants engaged in projects on ThinkCycle in chapter 5.

Thesis Summary: The thesis begins with a discussion of the nature of distributed cooperation and property rights (chapter 2), particularly for sustainable design innovation in online settings. I then describe the development and design of the online collaboration platform (chapter 3), and social and technical lessons learned in the process of development. I discuss the results of a study (in chapter 4) conducted with design courses in 2001 and 2002, examining the nature of design cooperation, learning and usage of the online collaboration platform. I also describe a follow-on study conducted on intellectual property rights (chapter 5), which examines the sociological rationale for innovators and teams in negotiating the nature of protection and dissemination of their design innovations. I suggest several recommendations and concrete mechanisms for dealing with diverse approaches to intellectual property in online settings. Finally, I conclude (in chapter 6) with the key challenges, lessons learned and research directions for future work.

2 COOPERATION AND PROPERTY RIGHTS IN THE COMMONS

The networked medium of the Internet lowers the technical barriers for distributed collaboration and peer production, however the challenges of creating and sustaining large social and cooperative enterprise are immense. This chapter is a survey of prior literature and current theories of cooperation and property rights, particularly in the context of distributed online communities.

The recent "Free Software" and "Open Source" movements have been influential in the software community; for many people, this notion of distributed production in the public domain appears appealing in different contexts of human enterprise. What are the social incentives, norms and mechanisms that emerge in such distributed communities to support peer production? Under what conditions is an open source approach effective and what are its serious limitations? Few studies manage to address such questions in a critical manner. While open source is appealing for 'socially closed-knit' and technically savvy communities, it presents many challenges for sustaining the social organization and productive capacity in diverse distributed networks.

Applying models of distributed peer-production towards knowledge-intensive design, which is traditionally situated in physical and cultural settings, requires careful consideration. What can we learn from cooperation, user innovation and social norms in co-located communities to understand innovation in distributed online settings? Transferring the open source model to physical knowledge-intensive domains like craft and product design, requires us to critically examine the nature of the design process, role of physical interaction, culture and "place" as well as the social norms and notions of intellectual property rights in such "communities of practice".

Distinct notions of property rights regimes emerge within different social settings, and conversely influence the level of conservation, access, exclusivity and incentives for productive capacity. We examine both private and communal property rights, and the relationship to the public domain. We consider property rights in the context of natural resource systems, small-scale product innovation as well as online digital content. Finally, we explore the key challenges and mechanisms that support intellectual property rights for grassroots innovators and subpatentable innovations. Many tensions emerge between perceived notions of protection, compensation, and public good. Appropriate policies must be carefully devised within specific contexts in a participatory manner, and facilitated by their own communal and institutional settings.

Greater clarity is needed to resolve diverse notions of what I generally refer to as "cooperation in the commons".

Open Source, Free Software, Public Domain and the Commons

There is some degree of ambiguity in the definition and usage of the terms *Open Source, Free Software*, *Public Domain* and the *Commons*, which are often used synonymously with each other.

Open Source usually refers to software (or source code) made available in the public domain under certain social/legal contracts, ensuring varying agreements for ownership, access and modification. *Open Source* software projects are usually undertaken, managed and maintained as cooperative efforts by individuals or groups in distributed geographic and institutional settings, though this is not always the case. *Free Software* primarily refers to software projects developed under the GNU GPL licensing scheme. The term *Free Software* was coined by Richard Stallman in the mid-1980's prior to *Open Source* however it has had limited usage and adoption in the mainstream, while *Open Source* has emerged in the late 1990's as a common term in the software community. Much of this has to do with the misperception of "free" as being unprotected dissemination, while it was meant to invoke democratic ideals of "freedom" for production of software code. *Open Source*, later coined by a group of software hackers including Eric Raymond, was a response to this perception trying instead to combine ideals of *Free Software* with principles of product-oriented economic payoffs for the mainstream software industry.

In dictionary definitions *public domain* is defined as either government owned land or unprotected property that is free for anyone to use. The term *commons* has been used in the British Parliament to represent non-titled citizens, agricultural fields in Europe prior to their enclosure and for public spaces in the US [Hess2001]. These terms embody notions of ownership (or lack there of), access, exchange and governance with respect to communal and public good to varying degrees. The interpretations of different scholars provides greater clarity:

> "The concept of the public domain is another import from the realm of real property. In the intellectual property context, the term describes as a true commons comprising elements of intellectual property that are ineligible for private ownership. The contents of the public domain may be mined by any member of the public." [Littman1990]

> "The commons: There's a part of our world, here and now, that we all get to enjoy without the permission of any." [Lessig1999]

> "In relation to the intellectual public domain, the commons appears to be an idea about democratic processes, freedom of speech, and the free exchange of information." [Hess2001]

Overall despite the similar usage of the terms, operationally to some extent one can distinguish reference to the *public domain* as to invoke ownership concerns, while that of the *commons* as to invoke notions of access, governance and exchange. Hence, in this writing we will refer to both terms under such distinct contexts where possible i.e. we will consider notions of intellectual property rights in the public domain, while social interactions and behavior in the commons. We will refer to *Open Source* and *Free Software* primarily in the context of software projects.

In this section we examine the conditions that support cooperative production in the commons and subsequently the role of intellectual property rights regimes emerging in this process. These two related social phenomenon are examined in the context of both distributed participants developing software as well as co-located communities engaged in product design innovation. Studies of the Open Source software movement as well as patterns of user innovation in design of sporting goods and handicrafts will provide some insights into behaviors, incentives and conditions for peer production in the public domain. We will consider studies showing how open source projects are actually conducted, and the conditions under which they succeed or fail. In the second half of this section, we consider the role of property rights in cooperative innovation; we look at the attributes of private and common property rights, and lessons from studies of property rights in natural resource systems. We then examine the politics of intellectual property rights in the context of technology innovation and access in developing countries. Finally, we consider key lessons for IPR in digital networks and distributed communities.

2.1 Distributed Cooperation: Lessons from Open Source and User Innovation

What does the literature reveal about open source initiatives? Why do people contribute freely to open source software (OSS) projects? What are the key issues for understanding online "cooperation" among different parties? This section examines a number of recent studies and writing on the open source phenomenon in software development, product design (sporting goods and handicrafts) as well as the notion of "peer-production" of information goods by distributed online communities. The key factors to consider are the incentives and challenges for distributed cooperation, and how they related to the context of knowledge-intensive design.

2.1.1 Social Incentives and Economics of Open Source Software

Though there has been a great deal of interest in the process of open source software development, the underlying social and economic mechanisms as well as its effectiveness as a productive mode of organization has been much debated.

In a recent study, economists Lerner and Tirole [2000] examine a number of social factors that are considered to contribute towards open source projects:

1. Altruism, though possible, does not provide a consistent or satisfactory explanation. Authors point out that altruism should not be particularly applicable in the software industry only.
2. Delayed Rewards or "Signaling Incentives" for individuals – namely:
    a. Open source contributions are more visible to outsiders than in closed-source.
    b. Personal initiative and responsibility in open source projects.
    c. Fluid Labor market in open source environment i.e. programmers can easily shift their efforts elsewhere, including source code when needed.
3. Reputation: Involvement in open source projects can serve as a point of entry to signal ones talent to peers, and potential employers.
4. Visibility, personal interest or critical nature of a project can lead to increased participation; however a relative loss in popularity may cause early abandonment.
5. Low possibility for large commercial payoff may allow people to contribute freely; however they may be tempted to move to proprietary mode or cease contributing if this condition changes.

Another recent survey of participants in open source projects[16] was conducted by Karim Lakhani with the Boston Consulting Group and Sloan School at MIT. The survey revealed several key motivations including 1) participating in an intellectually stimulating project, 2) improving their skills, 3) having an opportunity to work with open source code, 4) developing programs to solve both work related and personal needs. Hence the motivations suggest the key role for learning and problem solving in such initiatives, rather than commercial gains.

Lerner and Tirole suggest several mechanisms that encourage open source software efforts:
1. Lowering barriers for accessing and contributing to development projects – emerging with the spread of Internet and collaboration or code management tools like CVS.
2. IP and licensing agreements such as GPL, Free-GPL, Debian and other licenses.
3. Giving credit to contributors is essential to the open source movement. Reputational benefits provide real effects on developers, in some cases leading to tangible rewards.
4. Credible leadership to provide a vision, manage tasks, attract contributors and "keep a project together".

Many motivations for involvement in open source projects often cited include learning from experts, reputation and career benefits, personal interest in solving a problem etc. Rather than focusing on personal factors influencing individuals, it is perhaps more instructive to examine the institutional norms and social contracts established in the open source community that encourage this mode of production. Kelty [2001] cites an analogy with the sciences referring to work of the sociologist Merton, who focused on the institutional norms of science rather than the character of individual scientists. Merton [1973] asserted that recognition and reputation (play crucial roles in the incentive structure of science. Citation indices in science serve as a indicator of value and reputation, and a means of registering intellectual contributions. Latour and Woolgar [1979] refer to the non-monetary exchange in science by exploring the "cycle of credit" where reputation leads to funding grants and vice versa over time. Hence, reputation and credit metaphorically serve as currencies of economic motivation in science. One can argue that to a great extent similar institutional norms and mechanisms are at play in the open source software community.

2.1.2 The Limitations of Open Source: Conditions and Misconceptions

While there has been a great deal of interest in adopting the Open Source model, one needs to closely examine under what conditions it is truly an effective form of production. What is the social nature of open source projects? To what extent is it based on democratic community of distributed participants with diverse interest and expertise? Is it limited to software-based projects with highly technical developers and users? To better understand the role of community-based models in software development, Krishnamurthy [2002] conducted a study of 100 mature open source software projects on *Sourceforge.net* (an online software repository). His empirical

[16] http://www.osdn.com/bcg/bcg-0.73/BCGHackerSurveyv0-73.html

findings rebuke commonly held notions that most open source initiatives are based on intense contributions from large distributed communities. Some key findings suggest:

1. Most mature open source programs are developed by a small number of contributors. The median number of developers was 4 and the mode was 1. Only 29% of all projects had more than 5 developers while 22% had only one developer.
2. Most open source projects do not generate much discussion over email or online forums. Of the 100 projects 33 had no messages during the lifetime of the product development.
3. The number of developers working with a project was correlated with its age – older projects attracted more developers.
4. A smaller percentage of participants were assigned as project administrators in large groups. The median number of project administrators was 1.
5. In an informal examination of software projects listed on *Sourceforge.net*, Chandavarkar [2002] finds that nearly 60% are intended for developers and system administrators; among the 100 most active projects that list end users as the intended audience, 73 of them also list developers and sys-admins. Hence there is a greater focus on back-office functionality and the intended community is largely directed towards a "techie" audience.

These findings suggest a model of open source development, more akin to a lone developer (or cave) model of production rather than a large democratic and distributed community. Larger open source projects require greater publicity and the role of credible vision and leadership towards compelling challenges (as in the case of Linus Trovalds in Linux). Krishnamurthy suggests that it is important to "delineate the relative roles of individuals, communities and social networks" in the process of open source development, rather than focus solely on the active contributors to the product development. Non-developers often contribute feature suggestions, documentation, try out the software and provide bug reports etc. Chandavarkar speculates that the open source methodology "does well within technically savvy communities focused on their own needs, whose members are already patched into networks", while he expresses doubt over its ability to define requirements in a "non-techie" context". The organization of average open source projects resembles a limited access "cave" of elite developers, surrounded by technically savvy lead users without much control over the project, and other peripheral users with less involvement. Hence, one needs to rethink the traditional notions of democratic community collaboration and modes of production in such open source initiatives.

In a critical look at the Open Source movement, Nikolai Bezroukov [1999] believes that the Eric Raymond's bazaar model[17] [2001] provides an overoptimistic and simplistic view of the open source software (OSS) development process. Popular press often emphasizes successful projects, however the difficulties with aborted attempts are rarely highlighted. This creates an impression that "open source is a panacea and a magic bullet that will solve almost all difficulties." Though Bezroukov feels the overall approach has many useful attributes, particularly for learning, he outlines a number of problems and misconceptions inherent in the model (as it is generally perceived). I summarize some of the key issues here:

1. *Brooks Law:* Though it is often argued that a large number of distributed developers can be engaged in open source software development using the Internet, this does not eliminate the problems of coordination and integration that most complex systems require. Fred Brooks argued that the complexity and communication costs of a project rise with the square of the number of developers, commonly cited as Brooks Law. Though networks help mediate some of this overhead, the challenges of social organization must be addressed to enable large distributed software projects.

2. *Distributed Debugging:* It is often claimed that many talented developers can debug the same code in parallel without any coordination other than email; however there are many challenges particularly for large complex systems with a great deal of successive layers of non-documented code. Unfamiliar developers who enter a project late in the process

[17] http://www.tuxedo.org/~esr/writings/cathedral-bazaar/

have a momentous if not impossible task to resolve such difficulties. Bezroukov feels one should recognize the critical role of project management and documentation. There is also the question of the appropriateness of forcing gifted developers to solve such tasks, unless there are compelling incentives and rewards to have critical bugs resolved. Here some notion of ownership, control and stake in a project must be established.

3. *Cathedral vs. Bazaar:* The level of decentralization and democratic organization in open source software projects is open to review. In most large complex projects developed under time pressures, there is a need for centralized authority and management. In the Linux OS, there seems to be a mechanism in place whereby new code patches are submitted to core developers who filter and review them before sending them to Linus Trovalds who makes the final decisions weather such patches are worthy of incorporation in the OS. Hence there seems to be a centralized and hierarchical process to manage the integration of numerous distributed contributions, more akin to the *cathedral*.

4. *Quality of OS Software:* Bezroukov argues that simply because a project is open source, does not mean it would automatically yield the best outcomes. Despite the successes of Linux and the Apache server, there is no general implication that all OSS developed has better features and lower bug reports. There are many different variants of Linux with varying grades of stability and security, although the Apache server is often cited as having higher performance among web servers. However, there is no conclusive study that effectively compares the performance of different types of OSS systems with commercial or individually developed software, to resolve this question.

5. *Sustaining Individual & Cooperative Efforts:* For large voluntary initiatives sustaining the development of a complex system in a productive manner is immensely challenging. There is a tremendous responsibility for dedicated leadership who needs to manage the process, keep up with ongoing efforts and often assert authority. Without greater distribution of the workload there is a risk of "burnout" on the part of leaders and key developers, particularly when a complex production level system must be developed under short time constraints and without "critical mass" of supportive developers, users or resources to assist in their efforts. In addition, Bezroukov also points out that just as in any social setting, there are bound to be conflicts of interest, ego and status which must be gradually dealt with in the social norms and organization as such initiatives scale up. He takes a less than optimistic view saying "the rosy view of open source as an ideal community of constantly cooperating individuals is an illusion".

To better understand the nature of open source software development, Bezroukov finds it useful to consider it as a special case of academic research. This comparison with the scientific community suggests that open source may inherit many similar incentives, structures, and mechanisms. His analogies include the role of reputation vs. monetary gain in such communities, genuine interest and personal stake in the domain, and the nature of distributed cooperation and peer-review in the academic community. He likens the distributed software teams to that of informal communities of scientists that historically used hand-written letters to shares ideas and criticism. One example of conflict that Bezroukov cites "Like scientific communities, the free software movement is constantly driven by factional disputes over ideological and technological issues." He goes on to state "the problems of open source are by and large the same as those that confront academic culture and are better understood in this context."

A key insight he mentions is the potential influence of institutional setting, reputation and access that provides legitimacy and resource to ensure the success of cooperative initiatives. He notes the work of Nobel laureate Pyotr Leonidovinch Kapitsa investigating the phenomenon of the "tragedy of provincial talent" among Russian physicists - "Kapitsa understood that the proximity to leading centers of research and to members working at these centers greatly contributes to the acceptance of a discovery." Hence, Bezroukov feels "as in an academic community, direct contacts with influential community members and access to major centers of development are very important and can significantly reduce the barriers to the acceptance of an idea," Hence, several limited parallels can be drawn with the academic community that may be instructive in examining Open Source communities, however one must be cautious to recognize the unique social and institutional settings within which each operates. Overall, there are significant challenges for large-scale OSS development, and commonly held notions on why such initiatives succeed must be critically examined.

2.1.3 Challenges of Distributed Peer Production

Beyond the Open Source movement in software, one finds increasing evidence of distributed activities conducted online; as we will see here, most of these can be categorized as "lightweight forms of information production". In a widely cited paper, Yochai Benkler [2001] examines this phenomenon of "peer production" in contrast with market-based production activities. He states that the current information economy is largely based on property rights, contractual exchange, and hierarchically managed firms, while trends in the Open Source projects would seem to dispel such mechanisms. Though this observation would seem compelling at the surface, we have seen that even in Open Source communities, diverse notions of property rights, social organization as well as centralized and hierarchical management structures do emerge. Hence these assumptions can be problematic if they are not examined carefully, however they remain a central claim in Benkler's arguments towards novel forms of distributed peer production.

Applying Peer Production to Knowledge-Intensive Domains?

Benkler believes that the specialized attributes of distributed software production are not unique and can be found in other modes of information production and communication (even in mundane tasks like proofreading). His basic claim is that "different modes of production are better or worse at processing different types of information". He considers many different forms of peer production: 1) *Content* – e.g. identifying craters on Mars on a NASA website[18],
2) *Relevance/accreditation* – e.g. book reviews on Amazon.com or volunteer editors verifying links submitted to the Open Directory Project[19], and 3) *Value-added distribution* – e.g. Distributed Proofreading[20] of public domain "etexts" by volunteers for Project Gutenberg[21]. In all of these cases the tasks are information-based, well defined and easily discretizable. His main argument for distributed peer-production is that it allows people to "self-identify" for tasks they have competencies in; this he feels makes is better suited for activities in which human expertise is the main input, as long as coordination problems can be resolved. However much of the analysis is based on models of Open Source software and online interactions around information processing, review and production. I believe this model is problematic in product design and knowledge-intensive domains, without addressing a number of key problems arising.

The Problem of Incentives

Benkler considers the problem of incentives a trivial one if sufficient contributors can be involved. He feels that people are willing devote their free time to "creative play", based on behavior observed in the online contribution websites he mentions and the free software movement. I would say that this notion of "creative play" does not scale well beyond small transactions where a substantial product must be developed; here ones needs social mechanisms and incentives to transform creative play into responsibility for creative production. In the Free Software movement, incentives often cited are reputation gains and opportunity for subsequent consulting jobs. These are based on longer-term projects with implicit (or explicit) norms social contracts among the community created. However, Benkler states "As a practical matter, given the diversity of motivations and personal valuations on the productive activity itself and on the likelihood of desirable consequences from participation, the incentives problem is trivial." He believes that a collaboration problem solved on a large scale with thousands of individuals, easily resolves the incentives problem. Leaving aside the problem of orchestrating such a large collaboration, this

[18] http://clickworkers.arc.nasa.gov/top
[19] http://dmoz.org/
[20] http://promo.net/pg/
[21] http://charlz.dynip.com/gutenberg

still seems a rather naïve assumption as it views the distributed production as a kind of mass manufacturing with homogenous inputs without any notion of social norms, conflicting goals and ongoing interaction among the community of producers.

The Problem of Discretization

Benkler claims that the "modularity of the information product and granularity of its components" determine its capacity to be produced on a peer-production model. This kind of peer-production model would then be limited to domains where there are distinct and identifiable tasks that can be easily partitioned among distributed individuals. It would only seem to apply to simple transactions and service-based contributions which (like posting a document to be proofread etc). While in more involved design and knowledge-based activities such discretization and boundaries in production tasks are not clearly demarcated. Doing so effectively in itself is an intellectual exercise, which could presumably be peer-supported. However, as we will see in design-related activities the "design" often emerges from the social interactions among designers, stakeholders and experts. Hence partitioning all the potential design tasks beforehand is problematic.

The Problem of Coordination and Integration

Benkler states that the key problem for peer-production is that of coordination, integration and quality control over all the peer contributions; this he feels can be accomplished by either 1) iterative peer production of the integration function itself, 2) technical solutions embedded in the collaboration platform, 3) a norm-based social organization or 4) "limited reintroduction of market-based and hierarchical mechanisms". Though technical solutions can assist, there is a clear need for social organization of the coordination, management and integration functions, which means that a distributed community must be formed with clear (and perhaps evolving) roles, norms and abilities to enforce action. Benkler feels that if we can simply reduce the transaction costs involved in peer participation of projects, the problem of coordination is less critical – this I believe is a simplifying assumption overlooking the role of social organization and norms that emerge even in online communities. Transaction costs for an individual spamming a mailing list with inappropriate content are near zero, however this behavior is generally prevented by the social norms established in the online community.

The Problem(s) of Appropriation

Benkler believes that in this new mode of "commons-based peer-production" the absence of any property rights is a central organizing feature. He recognizers the role of common property regimes used by communities to monitor and regulate physical resources, using both formal laws and social norms. Based on prior work by Ostrom [1990], Benkler cites two issues that may be of concern: *provisioning* – process of specifying who receives goods vs. *allocation* – process of distribution of those goods. He considers them separate problems as he feels that if a resource were easily renewable and properly allocated then there would be no need for institutions to ensure provisioning. So Benkler considers peer-production of information a "purely provisioning problem". He points to a number of factors involved in provisioning and appropriation:

1. Once information is produced, there is no problem allocating it as it is *nonrival* (usage by one user does not impede others). According to this logic as the size of the pool of information production increases, free-riding (or appropriation) can be tolerated as long as there are sufficient contributors. In that case a high degree of appropriation by others (end users) would provide greater reputational gains to the producers.
2. Studies of Free Software show that "unilateral appropriation" in the form of commercialization for private profit would cause a negative effect on producers, who may subsequently choose to disengage or privatize their own efforts (through nondisclosure, property rights or seeking their own commercialization). Benkler makes an important point that individuals would be more likely to contribute their efforts (and implicit appropriation) by nonprofit entities like NASA rather than firms like Microsoft.
3. An important motivation for contributors is to have "indirect appropriation based on continued access to the joint project". For some contributors nondiscriminatory access in

the public domain may be a preferred means to reduce misappropriation. Adopting social contracts such as GNU GPL licenses mitigate the risks of appropriation to some extent.

4. Benkler mentions the need for (low-cost) "provisioning the integration function" i.e. assuring the quality of the contributions by peer review, automated methods, hierarchical organization or market-based initiatives.
5. Benkler finally proposes a notion of "cooperative appropriation" i.e. when a group of contributors or users develop a means to service or customize information goods produced, based on their reputation (indicated by level of contribution) in the peer community. This then transforms the process to one akin to common property regime.

Hence, there are a number of significant challenges for peer-production, the most critical of which seems to be the problems related to incentives and appropriation. We will review the literature in property rights in the next section to shed more light on problems of appropriation. Despite the limitations and problems of applying the model of peer-production, Benkler approach has implications primarily for *information production*. He believes that peer-production has "systematic advantages over markets and firms in matching the best available human capital with the best available information inputs." However in most design and knowledge-intensive domains, a simple partitioning of the tasks and creating coordination mechanisms by themselves is not entirely feasible, and the nature of incentives and property rights turns out to be somewhat more complex. Cooperative design and knowledge-intensive peer-production requires establishing what Chandavarkar referred to as a "community of practice" [2002], with common goals, incentives and norms for cooperation as well as social contracts and even notions of property rights and management. We examine these arguments later in the case of user innovation in sporting goods and handicraft producers, as well as in the work on communal norms and practices by Ostrom and others in the next section.

2.1.4 Patterns of User Innovation in Sporting Goods and Handicrafts

A recent study by Sonali Shah [2000] at the Sloan Business School at MIT examined patterns of innovation in sporting equipment, i.e. Skateboarding, Snowboarding, and Windsurfing, three relatively young sports with considerable evidence of user innovation. The study unveiled that in each sport the innovations were typically developed by early participants or lead users rather than equipment manufacturers, not even ones from allied fields. Young and technically unsophisticated users evolved their innovations by experimentation, field trials, and playing the sport, discovering problems and making revisions quickly. Some innovators supported their primary activity of playing the sport by making and selling their innovations, while others later founded small companies some of which become major producers of the equipment.

A few key findings are worth examining further:

- In these fields, innovating users had very limited ability to gain benefits from their innovations by commercial activities such as patenting and licensing their intellectual property to others.
- Manufacturers who patented innovations generally did not license it to others, preferring to benefit from producing and selling them. Individuals sometimes patented but innovators did not find patenting and licensing a successful means for gaining benefits. Only one case of patent & licensing was observed, 2 other cases showed patents overturned (in court) or licensing payments stopped as manufacturer's management changed (despite legal intervention).
- Low level of patenting was observed (17%) for a number of reasons: the technical novelty of the innovation was not considered patentable, innovators were not interested in patenting or immediate public disclosure made patenting impossible outside the US.
- Lead users had ready access to "sticky information" (situation and site specific information necessary for developing the innovation) having invested sufficient time playing the sport, which was not easily transferable to manufacturers.
- Lead users (and not manufacturers) are found to have greater incentives to innovate in small and uncertain markets.

- The costs of developing prototypes was low, developed using easily available materials and simple methods, while providing immediate benefits to the users i.e. being able to play their sports better.
- Of the expert practitioners who innovated, 71% sought to profit from their innovations by forming small lifestyle firms to manufacture and sell them as products. Innovators adopted the role of small producer as the "switching costs" (startup or entry costs) were quite low, relying on relatively low-tech and accessible methods of manufacture (with word-of-mouth advertising), while still allowing users to practice their sport & lifestyles.

Eric von Hippel [2001] believes this pattern of user-led innovation is supported by access to "user toolkits for innovation". Such toolkits give users the freedom to innovate by allowing preliminary design, simulation, customization, prototyping or evaluation in their unique settings. Hippel cites examples of such toolkits emerging in fields such as integrated circuits in the 1980's, which allowed customers to carry out need-related design work for themselves. This lead to better adoption of the products and standards by both end users and competitors in the industry. Hippel proposes that such user toolkits would emerge in many different industries with customized products and heterogeneous customer needs. One can argue that access to such user toolkits in the software industry in the form of common protocols and APIs, development platforms, and libraries of software components (as well as the fluid medium of the Internet) technically allowed distributed communities to join and support Open Source software projects. The grassroots users involved in modified sporting equipment innovations relied upon informal user toolkits with easily available materials and processes.

Another analogy towards cooperative innovation in product design is that of traditional handicrafts. Chandavarkar [2002] examines the role of social processes, place and communities of practice in the development of the crafts. Though there are many analogies with the Open Source movement, there are also critical differences and challenges for open collaboration in this domain. Chandarvakar cites a number of ways in which traditional craft embodies principles of open source methodology, including 1) practice and development of the crafts is situated in a community, 2) often the ideas belong to the entire community – if any single person comes up with an innovation then "it serves to extend the visual language of the entire community", 3) compensation is not expected for the ideas but for the expense of production and service provided, 4) Innovations are built on that of practices in the community in a gradual "bazaar" like manner, including peer review, 5) contributions to a craft are judged not only on utility but also how they extend the symbolic language for the community at large.

However, Chandavarkar points out two unique aspects of crafts that make the analogy with Open Source problematic: 1) outcomes of the craft community are embodied in tangible products of visual art and 2) the craft community is bound to a particular geographic context. These attributes suggest that the social, geographic and cultural context of the design and communities of practice plays an important role in shaping the sorts of products created, the nature of the cooperative activity and the norms for sharing and exchange among the community of practitioners. Chandarvakar believes the physical sense of place plays a critical role in design disciplines. While the open source methodologies rely on distributed "networks of practice" with people having functional or occupational links connected electronically, design disciplines rely on "communities of practice" with geographic, social and physical encounters that shape the memory and serendipity leading to collective design approaches and artifacts.

The work of Shah, Hippel and Chandavarkar suggests several critical aspects one must consider in projecting open source principles to user-led product design – 1) the "sticky" information or unique geographic and cultural attributes of the user community play an important role in the nature of innovations emerging (which makes it difficult to replicate by manufacturers and distributed communities), 2) user toolkits for experimentation and custom development gives users the freedom to innovate (these toolkits may emerge locally by the communities themselves), 3) The role of place and community setting is important in product design innovations, particularly where ideas emerge as a consequence of usage, social interactions and shared cultural context among the community. Supporting user-led product innovations in communities of practice requires new toolkits, interaction technologies and mechanisms to interface the co-located communities with distributed participants. In addition, we need to consider communal norms for social organization and production as well as distinct notions of property rights. We will discuss communal property rights and norms in the next section.

2.1.5 Summary: Rethinking Open Source for Cooperative Design Innovation

While the Open Source approach is considered appealing and yet challenging even in the context of a technically savvy distributed software community, applying it towards knowledge-intensive design that is traditionally situated in physical and cultural settings, requires careful consideration. The networked medium of the Internet lowers the barriers for distributed collaboration and peer production, however the challenges of creating and sustaining large social and cooperative enterprise are immense. It is important to recognize the nature of social incentives including status and reputation, learning and skills enhancement, and the presence of credible leadership, determined actors (lead developers and users) and legitimate institutional settings. In contrast to the perception of most Open Source projects as large scale distributed and democratic initiatives, most efforts are comprised of small, highly technically savvy teams (or individuals) with a strong personal interest in the outcomes. The nature of social organization is usually more like a close-knit circle of key developers with some centralized or authoritative control, surrounded by lead users and others with less involvement. Like any communal organization, the community must gradually sort out conflict, control and appropriation of intellectual work. Transferring the OSS model to knowledge-intensive tasks like craft, hardware and product design, requires us to critically examine the nature of the design process, role of physical interaction, culture and "place" as well as the social norms and notions of property rights in such "communities of practice".

2.2 Property Rights: Affordances and Conflicts for Innovation

Individual and cooperative production occurs within social and institutional settings, which determine the nature of norms, incentives, responsibilities and mechanisms for access and protection. Distinct notions of intellectual property regimes emerge within different settings, and conversely influence the level of conservation, access, exclusivity and incentives for productive capacity. Here we examine both private and communal property rights, and the relationship to the public domain. We consider property rights in the context of natural resource systems, small-scale product innovation as well as online digital content. Finally, we explore the key challenges and mechanisms to support intellectual property rights for grassroots innovators and subpatentable innovations. Many tensions emerge between perceived notions of protection, compensation, and public good. Appropriate policies must be carefully devised within specific contexts in a participatory manner, and facilitated by their communal and institutional settings.

2.2.1 Understanding Private and Common Property Rights

There are many important lessons that can be derived from how natural resource systems such as farms, fisheries and water resources are communally managed; these are clearly relevant to intellectual property regimes today. Elinor Ostrom [2000] contrasts the role of private and common property rights in the context of natural resource use patterns, pointing to the long ongoing debate about efficiency, equity and sustainability of different property regimes. The dominant view among legal and economic scholars has generally been that private property is superior to common property, however recent research challenges these presumptions.

Most economists consider private property rights to provide key incentives for owners to maintain resources and ensure productive utilization, while minimizing "free riding" by others. There is concern that communal property regimes do not invoke a direct relationship between individual contributions and long term benefits, such as from farmers who belong to agricultural cooperative vs. own and/or manage their own farms. Ostrom cites economists who presume 3 main sources of inefficiency: 1) *rent dissipation* i.e. not being able to capture value from communal use, 2) *high transaction and enforcement costs* to devise rules that allow mutual sharing without misuse, and 3) *low productivity* i.e. not having incentive to work hard to gain private returns. Hence private property rights are assumed to have a direct impact on economic productivity of natural resources.

Ostrom points to scholars such as Henry Maine who conducted extensive research in Indian and Germanic village communities (in 1861), and concluded that joint-ownership preceded notions of private property. This work led to much debate and a flurry of publications that had much legal and political significance. However beliefs about the merits of private property led to legislation in Europe to eliminate collective landholding rights and allow individuals to take over communal properties. In newly independent developing countries many collective properties and resources were often either privatized or held by the government, however mechanisms for operating and conserving them were not usually put in place, leading to a great deal of mismanagement, waste and inequitable distribution in many cases.

Both private and common property rights regimes require emergence of "rules and rulers to establish, monitor and enforce a property system". Both rulers and participants may specify or co-opt such rules in a manner to resist or benefit to the determent of others. Hence the so-called rent-seeking behavior is to be expected not only from participants but also the rulers. This indicates that neither private or common property systems are immune from outcomes of rent-seeking or mismanagement. Indeed one can easily find examples of both well-managed and poorly utilized resources among both private and common property regimes.

Common Property vs. Open Access

Ostrom clarifies the key difference among common property and open-access regimes; where as in *open access* no one has the legal right to exclude anyone one else form using a resource, in *common property* members of a clearly defined group can legally exclude nonmembers. There are few truly open access regimes for natural resources (like open seas and air) however some such as local grazing areas, inshore fisheries and forests are effectively treated as such; these are generally either 1) not contained within national boundaries, 2) no entity has laid legitimate claim to them or been able to enforce exclusion of non-owners, and 3) they may be consciously designated as such to guarantee access to the public. Some open access regimes lack effective rules defining property rights while others simply cannot enforce existing formal rights.

Ostrom makes an important point that the confusion between what is considered open access vs. common property has paradoxically led to a rise in local resources that are effectively treated as open access particularly in developing countries. The common property regimes that controlled streams, grazing or forests had evolved over a long time but were "rarely given formal status in the legal codes of newly independent countries". The nationalization of such resources as government property led to less effective and efficient management. The institutional arrangements informally devised by local users to limit usage of such resources (hence conserving them for centuries) had been delegitimized while the state lacked resources, expertise or personnel to monitor such resources; this effectively led to a conversion of such resources under common property regimes to that of de facto open access (some of which led to disastrous consequences).

Therefore this distinction between open access and common property is critical among intellectual property regimes as well, suggesting the role for community norms and mechanisms to manage shared resources, provide incentives for sustained innovation, and limit access or disclosure as deemed appropriate.

Taxonomy of Property Rights

Ostrom defines a property right as an "enforceable authority to undertake particular actions in specific domains". She outlines five main types of property rights: *access, withdrawal, management, exclusion,* and *alienation* each of which can be separately assigned to individuals or "collectivities". Alienation refers to the right to sell or lease management or exclusion of rights i.e. serving as a means to negotiate all other rights. In economics, private property is defined in terms of alienation i.e. obtaining legal contracts to negotiate rights, and regimes that do not support alienation are considered ill defined (as stakeholders cannot trade their interests or others purchase the system as a whole). Ostrom stress that it is important not to focus on one notion of property right but on five separate classes of rights that individuals or collectivities may hold. Any combination of these rights defines the operational nature of regime at different times for different participants (like owners, proprietors and claimants). For example, access and use of certain lands may be divided into so called "tenure niches" that vary by season, use, space or technology. One set of users may own rights to harvest fruits from trees while others own the rights to the timber, hence the tenure niches may overlap. Diverse schemes may be devised by participants to minimize interference or support rotation for utilization among shared resources.

In some cases having rights of a proprietor vs. owner in agricultural settings did not affect productivity however in densely settled regions, the absence of a title (i.e. ownership rights) reduced a farmer's ability to sell the land or gain collateral for investment. Thus Ostrom points out a key finding from such studies is that "no type of property-right regime works equivalently in all types of settings".

Communal Property Rights

Communal property rights are shared by groups of individuals when they have formed an organization (formal or informal) that exercises such rights of management or exclusion in relation to some resource units produced by the system. In her prior work "Governing the Commons" [1990], Ostrom shows that "all communal groups have established some means of governing themselves in relationship to a resource", though not all are formally organized or legally supported. In a study of grazing lands managed by Swiss peasants, Netting [1981] finds that the same individuals used different property systems simultaneously i.e. both private (for family-owned parcels of land) and communal (for grazing lands on Alpine hillsides). Local communities themselves devised local rules for their own use. Interestingly, the nature of property rights system adopted depended on the attributes of the resource. Netting identifies five attributes conducive to development of communal property rights, which generally include low production value (per unit area) and returns for intensified investment by any individual while greater economies of scale for infrastructure and utilization of large areas.

Netting shows that recognition that cooperative rather than individual efforts yield greater returns in utilizing such resources as well as a need for sharing in economic or environmental risks, naturally leads to emergence of communal mechanisms for governance. In particular, Ostrom cites many studies that indicate, "When no physical or institutional mechanisms exist for sharing risk, communal property arrangements may enable individuals to adopt productive activities not available under individual property rights". This is also supported by studies, which show that the variance of productivity of land is associated with the size of communally held parcels allocated to grazing.

Studies of communal property systems consistently indicate that they do not exist in isolation and are usually coexist with individual ownership e.g. joint and private irrigation systems managed by farmers. In addition, Ostrom shows that "formally recognized communal systems are usually nested into a series of governance units" that complement the skills of participants involved in managing smaller units from local villages to federations. Overall much evidence shows how communal systems instead of being inefficient, effectively deal with diverse local problems with low transaction costs. However the performance of these systems varies substantially like all property rights systems (including private enterprises). Ostrom characterizes several attributes of participants that influence the performance of their communal systems, generally related to having accurate and easily available information, common understanding of risks and benefits, generalized norms of reciprocity and trust, long-term stakes in the communal resources, and ability to develop low cost mechanisms for monitoring and regulation. Furthermore, Ostrom states that many of these attributes are affected by the larger regime within which the system is embedded – "If the larger regime recognizes the legitimacy of the communal systems, and is facilitative to its self organization... the probability of participants adapting more effective rules over time is higher". Hence the institutional setting and support plays an important role in the nature of effective communal property rights systems emerging and in their sustained operation.

Finally, Ostrom stresses the importance of participatory design and implementation of property rights systems, so that participants consider such rules legitimate, fair and effective; in the absence of shared ownership of the property rights regime itself, there is greater incentive to devise evasive strategies. A paradoxical notion is that the "very process of allocating quantitative and transferable rights to resource units may undo some of the common understandings and norms that allowed communal ownership system to operate" at low transaction costs. Hence, the way in which a property rights regime is introduced or facilitated within a community is a critical aspect of ensuring its acceptance, governance and effective sustained operation.

Key Lessons from Private and Communal Property Rights

1. There is a role for both private property rights and common property rights in any resource system; both provide different benefits to participants. Neither approach by itself ensures equity, efficiency and sustainability by itself. However their effectiveness is influenced under certain social and institutional settings, and by specific attributes of both the resources and participants involved. No property-right regime works equivalently in all types of settings. Private and communal rights regimes often co-exist in the same setting.
2. Both private and common property rights require emergence of effective rules to establish, maintain and enforce such rights. In the absence of effective formal or informal agreements and low-overhead monitoring (or low transaction costs for enforcement), rent-seeking behavior can be expected by both participants and rulers.
3. A useful distinction between common property and open access regimes enables one to recognize the role for community norms and mechanisms to manage or restrict shared resources. Open access does not ensure that resources will be well maintained and conserved; communal mechanisms can support monitoring and resource sharing.
4. It is important not to focus on any one notion of property right but consider different classes of rights (such as access, ownership, proprietorship) that individuals or collectivities may hold. Any combination of these rights allows different participants to utilize and manage the resources depending on their skills or needs and the limited availability or value of shared resources. A system of such differential rights may emerge informally or formally, and defines the relationship and responsibilities of participants.
5. In the absence of physical or institutional mechanisms for risk sharing, communal property arrangements may allow participants to establish productive ways of utilizing and governing shared resources.
6. The legitimacy and facilitation offered explicitly or implicitly by the institutional setting within which the resource system is embedded, increases the likelihood of the property rights system being more effective.
7. An effective property rights system requires participatory design and implementation to ensure participants perceive it as being fair and legitimate, while taking responsibility to maintain, monitor and enforce it. However, introducing notions of quantitative and transferable rights may undo common norms and understandings that allow such communal systems to operate. Hence there is a risk in formalizing a property rights regime without examining its influence on existing community norms.

We will consider these property rights issues in the context of design innovation among online communities later in this section.

2.2.2 Emerging Politics of Intellectual Property Rights in the Public Domain

The historic notion of property rights as embodied in mechanisms to protect natural resources such as land are clearly at play today in the emerging notions of intellectual property as well. In a renowned essay, James Boyle [2001] likens the current intellectual property regime to that of "The Second Enclosure Movement". He refers to the first English Enclosure Movement from the 15^{th} to 19^{th} century, which was an effort to turn common lands into private property. The

Enclosure movement had both positive and negative effects. Some considered it to be a means for inefficiently managed common land to be transferred to private owners who had better incentives to invest, maintain and make the land more productive. "Strong private property rights and single entity control avoid the tragedies of overuse and underinvestment". However, others would claim that enforcing such property rights imposed devastating costs on some segments of society such as converting freeholders who farmed on the lands of generations into debtors and seasonal wage laborers, disrupting traditional social relationships and communal norms, and as Ostrom points out, loss of many communal mechanisms to ensure conservation and access.

Boyle suggests that we are now in the middle of the second enclosure movement, one he calls "the enclosure of the intangible commons of the mind" where previously common and uncommodified intellectual property is being enclosed using formal property rights like copyrights and patents. A classic example is that of human genome where the state argues for extending property rights to ensure investment and commercial incentives to produce new drugs and gene therapies, while opponents argue that the genome should not be owned as it is the "common heritage of humanity". In addition some critics have argued that a monopoly over the property rights held by private companies and individuals in areas such as the human genome also introduces "bottlenecks and coordination costs that slow down innovation". Heller and Eisenberg [1998] refer to such bottlenecks caused by property rights as the *transaction costs* that create "The Tragedy of the Anti-Commons". Boyle points out that rather than focus on the popular rhetoric and naturalistic assumptions, economists concentrate on the "efficient allocation of rights" necessary to spur innovation.

Natural Resources vs. the Intellectual Commons

One can notice this expanded process of enclosure in many different domains – business method patents, software patents, increasing restrictions on digital media (from the recent Digital Millennium Copyright Act), regular extensions of copyright terms by the US Congress, European database protection, and overall it seems that patents are being applied for ideas that previously would have been considered common facts, public knowledge or simply unpatentable. Each of these clearly erodes the ability for production of ideas in the commons.

However, Boyle points out three main distinctions between the natural resource commons and intellectual commons that should allow us to question many of the assumptions about property rights today:

1. *Non-Rival:* While utilization of land is generally mutually exclusive and causes degradation or scarcity form overuse, the ideas, designs and information (like gene sequences and MP3 files) is generally "non-rival" i.e. usage by one user does not interfere with another.
2. *Non-Excludable:* Creators cannot easily exclude others from using their creations (information and design) as current network technologies allow such access and usage with nearly zero marginal cost. Hence, the argument is that intellectual property rights are necessary to provide incentives for creation and allow creators to recover costs.
3. *Derivative:* Increasingly information goods (and even hardware designs) are often developed on the basis of existing information or designs, even including those fragments in their production. Boyle states that every potential increase of protection raises the cost of and reduces access to those raw materials.

Hence, the key problem in the intellectual commons is that of incentives, costs and conditions to create the resource rather than its overuse, unlike the physical commons of the first enclosure movement. Here Boyle, makes a critical argument (which is also echoed by Benkler in his notions of "Peer Production") that although network technologies like the Internet lower the cost of illicit transfer, copying or usage, "the same process also lowers the cost of production, distribution, advertising and dramatically increases the size of the potential market. Is the "net" result, then, a loss to right-holders such that we need to increase production in order to maintain a constant level of incentives? A large, leaky, market may actually provide more revenues than a small one over which one's control is much stronger." Hence with online access, search and archiving, it seems in many regards that the strong protection of content can be counter-productive to both the process of innovation and potential economic payoffs. Intellectual property protection becomes an automatic response as a solution to the problem of preventing access or protecting potential revenue, rather than as a means to create conditions for innovation and new models for recuperation of creative efforts. Boyle states that paradoxically "protection of the commons was one of the fundamental goals of intellectual property law" and that the "burden of proof should be on those requesting new rights to prove their necessity".

An Anti-Enclosure Movement: Environmentalism for Intellectual Property?

There is evidence of a counter-movement now, shall we say the "Anti-Enclosure Movement" for intellectual property rights pushed by both Free Software and Open Source advocates lead by hackers like Stallman, Trovalds and Raymond as well as academics and legal scholars like Boyle, Benklar, Samuelson, Littman, Lange and Lessig. Instead of merely criticizing the costs of intellectual property protection, the rhetoric is shaped by a defense of the "public domain". There are 3 main philosophical approaches used in this defense: 1) Scholars frequently cite the *constitutional protection* afforded to the public domain, in arguing against extension of copyrights and patents. 2) David Lange [1981] argues "the recognition of new intellectual property interests should be offset today by equally deliberate recognition of *individual rights in the public domain*." 3) Benkler focuses on the role of the public domain in *information production and free use* i.e. being uncontrolled and costless. Lessig [2001] refers to the commons as a free resource, which is "not necessarily zero cost, but if there is a cost, it is neutrally imposed, or equally imposed cost." Finally Boyle notes that the notion of freedom invoked in intellectual property rights ought to be one of "non-discriminatory access"; maintaining unprivileged innovation by removing monopoly control rather than seeking costless or "free" access.

An important point that Boyle and Samuelson [2001] make is that despite the rhetoric of free and open source software movements about the public domain, free software under General Public License (GPL) is legally based on property contract. The terms of fair use, access and ability to make changes to Free Software under GPL agreements relies on intellectual property rights. "The free software movement attempted to build a living ecology of open code, where the price for admission was your commitment to make your own incremental innovation part of the ecology too." Though free software does not fit neatly into the "total freedoms" expected in the public domain, the social agreements are consistent with the notion of communal property norms and mechanisms (as mentioned earlier in the work by Ostrom and others). Hence it is important to recognize that in most cases cooperative action and property rights in the network commons can be effective, not due to free unrestricted access, but by establishing communal norms for access, distributed creation and management of the information resources and cooperative products. These norms must be defined and/or adopted by the community itself over time to make the peer production an effective and sustainable enterprise.

Boyle shows that there are many different conceptions of the "public domain", just as there are many different "properties". The notions of "free", "public domain", "commons" and "enclosure" are not always consistent with each other, having different meanings in different contexts. For example Boyle states "It may be that the commons is constructed around the twin notions of preventing monopoly control over network protocols in order to preserve innovation, while still allowing for the type of collective management that will avoid a tragedy of the commons." This is an important aspect to understand, as it influences the visions and nature of cooperative arrangement pursued by different communities with different interests. So there should be a role for multiple visions and theories on the public domain. However, there are some clear overlaps in the common ideals pursued in all such notions and greater coherence among the shared goals is useful. In this regard, both Boyle and Samuelson argue for a "new politics of intellectual property" to protect the public domain, analogous to the role of the Environmental Movement in conserving our natural domain. Inventing a concept of the "environment" in the 1960's enabled a powerful movement to emerge from diverse interests, to lobby cooperatively to protect their distinct visions of the environment. Boyle and Samuelson push for a coalition of scholars, authors, artists, innovators, private and public institutions to ignite a similar movement to promote open and non-discriminatory policies for the public domain and balanced intellectual property laws.

This brings into question: what is the role for online communities like ThinkCycle to adopt novel and progressive policies to support their evolving vision for design innovations in the public domain? And to what extent this can influence property rights awareness and activism in other communities? We will consider the implications in concluding sections.

2.2.3 Rethinking Property Rights for Small-scale and Subpatentable Innovation

Much of the debate on intellectual property for patent protection vs. public domain focuses on "breakthrough" R&D innovations with big market players and high commercial stakes (such as in biotechnology). However, there is little discussion of how to deal with small-scale innovations among grassroots innovators or small industries, which are not always considered patentable. Many such innovations emerge in university research, cottage industries, and particularly in rural or non-academic settings by grassroots innovators. What set of policies can stimulate and protect small-scale innovation while supporting access and peer production in the public domain?

Reichman [2001] highlights these concerns and potential approaches towards what he calls "the puzzle of grain-sized innovation" particularly in the context of small-scale industries and developing countries. He suggests that there has always been a perception that if innovations can be kept proprietary or under legal cover, innovators can expect a period of "natural lead time" during which they recoup their effort and investments through licensing or manufacturing. Since the early industrial revolution, there has been concern that once products are distributed to the market, competitors can easily imitate them without having to incur R&D costs of their own. The legislative response has typically been a strengthening of exclusive property rights through patents and copyrights, providing an artificial lead-time. Reichman feels that an expansion of "poorly conceived and overly protective intellectual property rights may progressively discourage investment in subpatentable innovation across large segments of the global marketplace." There is typically no assessment of the unacceptably high social costs of exclusive property rights from the diminished opportunity for small firms and innovators to compete.

Property Rights vs. Liability Mechanisms: The Green Tulip Problem

Reichman previously studied why local design industries in some countries with relatively weak protection (like Italy) had done better than those with stronger protection (like France). He found that there was often a "recurring cyclical movement between states of perceived underprotection and states of perceived overprotection", where countries periodically swung between adopting weak to strong protection over a two hundred year period. The key problem Reichman found was that in all these regimes, small-scale innovation was often dealt with "by means of a *property rule*, whereas the problems entrepreneurs actually faced resulted from the failure of a *liability rule*." Reichman believes that a properly devised liability rule better addresses the problem of follow-on innovation for subpatentable designs, with fewer social costs. He demonstrates this using a hypothetical scenario called the "green tulip" problem.

In the hypothetical problem proposed by Reichman there are three firms that breed tulips: Breeder A develops a green tulip for the first time, however it is unable to have commercial success. Breeder B combines this variety and breeds a red, white and green tulip; this product is commercially successful with consumers. Finally other breeders, designated as Breeder C use both A and B's varieties to develop an array of different tulips. The question in this scenario is how different IPR regimes deal with small-scale innovation i.e. how the first comer (A) is able to recoup her investment while allowing others to compete with follow-on innovation. It is assumed that the green tulip is a small grain-sized innovation that is easily replicable by others and subpatentable (i.e. cannot be patented due to existing standards regarding nonobviousness). Reichman then considers how the puzzle is resolved within three different patterns of IPR:

Raw State of Affairs: Here there are no exclusive property rights and free competition is allowed, hence Breeders B and C may easily profit from A's original innovation. If Breeder A is unable to make his product commercially viable, others can potentially take the market with no means for A to protect or recoup her R&D investment.

Copyright-Like Regime: Breeder A is able to take up a weak form of intellectual property protection based on the copyright model. This does not necessarily deny B from developing a derivative product; in most cases courts allow free competition where others provide value-added contribution by investing their own time and effort (whereas a direct imitation would invoke infringement claims). So Breeder A has a very weak claim of relief under copyright-like regime, hence she may not be much better served in terms of recouping her investment under this regime either.

Patent-Like Regime: In a regime modeled around patent protection for plant varieties (such as utility or design protection laws), Breeder A could invoke a stronger right to deny unauthorized follow-on innovation from others, and hence retain lead time or competitive advantage. Here Breeders B and C will require a license from A to develop their follow-on products, having to negotiate terms and pricing while they are uncertain whether they can make any revenue from their potential innovations. Breeder A can choose to deny licensing to others or do so selectively to maximize her own competitive advantage. If Breeder A's initial product was not commercially successful and other breeders are prevented from follow-on innovation by having to make their own high-risk R&D investment or licensing/infringement barriers, then its quite possible that follow-on derivatives of A's tulips are never successfully introduced in the market. Other breeders would seek to develop their own original tulip variants to take advantage of strong patent-like protection. Hence there is little incentive for follow-on innovations and subsequently commercial successes, aggravated by additional risks and transaction costs involved. This leads to lack of novel products or high costs for consumers and a denial of technically beneficial knowledge among the entire breeder community, resulting from access and lack of new industry-wide investments and follow-on research.

Social Costs of Exclusive Property Rights on Producers and Consumers

This scenario can be easily mapped to the case of generic drugs or small medical innovations for critical treatments in developing countries, and one can see the need for supporting follow-on innovations and access to novel and affordable products for poor consumers. The scenario shows that poorly conceived intellectual property regimes can not only hamper innovation among producers but also induce high social costs on all consumers. Conferring a monopoly to any one producer through exclusive rights leads to many flawed economic outcomes. As Reichman explains "While the public stands to benefit from the green tulip innovation (despite the tepid initial consumer response), solving the free-rider problem by misbundling exclusive property rights imposes burdensome transaction costs on the relevant technical community, frustrates entrepreneurial initiative, and saddles the public with the social costs of misdirected, top-down incentives that deny equally capable second comers access to inputs from the public domain."

Another issue is that most exclusive property rights do not take into account the role of the community of producers and innovators in the process of developing the innovation from their combined knowledge in the area. While protecting and recognizing individual innovators, these approaches "undermines the community own interests by artificially restricting access to the public domain interests on which it collectively depends" as both Boyle and Benkler have previously suggested about the role of peer production. Reichman goes on to say that "by rewarding individuals with strong exclusive property rights for routine applications of the community's technical know-how to industry, the system tends to make that shared know-how artificially scarce" leading to higher transaction costs and ultimately greater social costs to both the community of innovators and consumers (for these small subpatentable innovations). Finally, the overall outcome of such protective regimes is that community knowledge is divided up into smaller parcels withdrawn from the public domain, leading to greater barriers for knowledge-sharing and small-scale innovation.

Compensatory Liability Scheme for Subpatentable Innovations

A solution to the green tulip puzzle would need to fulfill seemingly contradictory requirements: 1) allow innovators to recoup their investment, 2) prevent others from free-riding without contributing, 3) avoid barriers to entry for follow-on innovations, 4) allow dissemination of knowledge in the public domain (or within the community of producers). Reichman believes that some form of *liability principles* rather than property rules provide a more appropriate solution. A liability essentially system obliges "second comers to pay equitable compensation for borrowed improvements over a relatively short period of time." Simply stated in a liability principle, other breeders must compensate Breeder A for use of her know-how during a specified period of time only (relatively short), while Breeder A cannot deter others from using her innovation under those terms. Finally Breeders C must compensate both A and B during that time. Compensation is based on the value added by follow-on innovations (a sliding scale of modest % royalties). At the expiration of the period of protection, the small-scale innovation would come into the public domain. This creates a functional equivalent of natural lead-time rather than an exclusive property right, encouraging compensation, competition, follow-on innovation and minimizing free riding.

Implementing such a *compensatory liability scheme* requires: 1) a subject domain for which the scheme is applied that Reichman calls an "industrial compilation", 2) flexible standards of novelty (to protect subpatentable innovations), 3) consensus on a period of artificial lead time allowed for a specific "industrial compilation", 4) national online registry system for tracking claims, 5) arrangements for dispute resolution and infringement (built into the online system to some extent). Hence within a specific industry like plants, handicrafts, digital music, or say innovations for the underserved, there needs to be agreement on the specific nature of the liability scheme adopted. In a sense it constitutes a "third intellectual property paradigm" that can be further developed while it coexists with existing patent and copyright regimes. The key implication of the liability approach is its focus on the community of producers as a whole (within small industries) rather than any individual innovator, encouraging investment, exchange, compensation and arbitration within the community, while enriching know-how in the public domain over time. We later consider the role of such a liability scheme for distributed communities in digital networks.

2.2.4 Challenges of Property Rights for Grassroots Innovators in Developing Countries

While the notions of intellectual property rights we have considered so far apply broadly to innovations in most settings –high-technology, industrial, academic, small scale manufacturers and innovators – however, there are many specific constraints and problems that arise in the context of grassroots innovators and communities in developing countries.

Contested Domains: Private, Community and Public

There are clear parallels between the approach towards property rights over natural resources, and that of individual and community knowledge in developing countries. Prof. Anil Gupta [2001] has suggested that these "Contested Domains" of knowledge, resources, rights and responsibilities must be clearly understood, along with the role of effective incentives for reciprocity, social equity, conservation and innovation. In contrast to the dichotomous notions of property rights, Gupta indicates there are *contested domains* among *private*, *community* and the *public domain*. One notes in written works that western scholars often assume the knowledge and resources in developing countries as belonging within a community or part of the public domain. The role of independent innovators and individual rights (particularly of poor rural innovators) is often overlooked or under-represented. Though individuals regularly derive knowledge, resources and insights in their community settings and while boundaries between individual and communal rights are not clearly demarcated, Gupta strongly advocates for a need to recognize individual creativity and provide appropriate incentives for innovation, sharing and conservation.

Gupta has often stated that policies that allow individual and community knowledge to be easily placed in the public domain without prior informed consent and reciprocal benefits, are not just problematic but "rob the poor of the only thing in which they are rich". Hence, there seems to be a threat to the intellectual property rights of grassroots individuals and communities, not only from exploitation by the state and multinational corporations, but also paradoxically from the increasing drive towards open intellectual property regimes among scholars and activitists arguing for the public domain. How does one resolve these seemingly diametric interests that each strive for the public good?

Gupta states that knowledge produced by individuals or groups may be diffused locally and characterized as community knowledge, while diffusion outside leads to knowledge in the public domain. However, even within the individual or community knowledge "there may be elements which are restricted in scope or in terms of accessibility while others may be in the public domain" while other aspects may be kept entirely confidential and only accessed with restrictions. Another important factor mentioned by Ostrom is that in many indigenous communities, heritage and knowledge is not viewed in terms of property but as responsibilities, which are not commodified like property rights. Hence, it is not feasible to apply any one notion of IPR across all forms of individual or community knowledge. Gupta [1995] shows that much of the "contestation emerges when the producers and users have unequal access, ability and assurances" in these overlapping domains of private, communal and public knowledge. However, a goal is to ensure that there are mechanisms and incentives for innovation, conservation, and attribution to innovators, while non-discriminatory (and perhaps regulated) access to such knowledge to benefit other communities.

Supporting Intellectual Property Rights for Grassroots Innovators

In his writings, Gupta points out several challenges and approaches for IPR in such settings:

1. *Formal vs. Informal Knowledge:* To provide IPR protection one has to characterize grassroots knowledge in terms of existing formal scientific knowledge, to help establish novelty and non-obviousness claims. This is rather difficult and requires a greater engagement in grassroots innovations by the scientific community.

2. *Documenting Oral Knowledge:* Very often rural innovation and traditional knowledge is disseminated orally and not documented in written form, hence verifying prior art for infringing patents becomes problematic in such cases. The *Honey Bee* initiative[22] has been documenting grassroots innovations for over 10 years through a network of volunteers, and disseminating many through printed publications in local languages (with the permission of innovators).

3. *Grace Period for Grassroots Innovations:* Recent disclosure of knowledge by innovators (to external parties, researchers or in the public domain) should not pre-empt them from seeking property rights. Not having awareness of IPR and lack of resources to invest in their enterprise suggests the necessity of "special grace period" for protection and to extend their lead-time.

4. *National and Global Registries of Small Scale Innovations:* Preventing patents by companies on traditional and contemporary knowledge in communities requires a mechanism to register all prior and recent innovations in a easily searchable and verifiable form. Digital libraries for registering traditional knowledge have been proposed by many scholars, and Gupta cites some efforts undertaken by the Government of India. A global system would be very useful for resolving conflicts in claims made by patent applications and provide an affordable registry for innovators. Many groups such as the Third World Network [Nijar1996] have proposed Community Intellectual Rights (CIR) and mechanisms like "registry of invention", while SRISTI [Gupta1995] has proposed an "International Registry" with a focus on disclosure rather than examination of novelty and non-obviousness. This approach reduces filing costs by placing the burden of verification at the time of patent infringement or conflict. The *CreativeCommons*[23] was established by MIT faculty Hal Abelson and Law faculty from Stanford, Harvard, and Duke. It provides a

[22] http://www.sristi.org/knownetgrin.html
[23] http://www.creativecommons.org

novel online mechanism to register and use copyrights for creative works. One could consider a similar approach towards patentable or subpatentable design innovations.

5. *Collective Management of IPR:* Gupta suggests a "collective management system" for institutional support of small innovators to reduce transaction costs for seeking protection. Though Gupta assumes that the primary role is for support of patent applications, however it seems that such a collective system not unlike the "industrial compilation" mentioned by Reichman could provide an array of mechanisms like and support for managing IP within an industry, like registry, licensing schemes, conflict resolution, patent pooling, knowledge sharing etc.

6. *Protection Schemes for Small Scale Innovations:* Gupta points to the need for a national patent system for small innovations where short-term protection is granted (8-10 years) within 3 months, with a maximum of 5 claims and small fees. To some extent this is not unlike Reichman's notion of compensatory liability protection for "subpatentable" innovations – the key distinction is one of seeking exclusive property rights by filing patents in the current IP regime vs. compensation and lead time by developing an agreement regulated and enforced by countries or the industry involved.

Gupta argues that notions of intellectual property must be examined within the context of *intellectual capital* (social and technological interactions), *natural capital* (biodiversity and resources), *social capital* (communal and institutional arrangements), and *ethical capital* (norms of transparency, accountability, reciprocity and equity). Each of these influences how intellectual property is perceived and governed; they are clearly different in diverse communities. To be effective and equitable, any IPR policies proposed must take into account such aspects.

2.2.5 Summary: Supporting Access, Rights and Liabilities for Innovation

We must examine questions about intellectual property rights within the context of private, communal and public spheres – there are different incentives, responsibilities, norms and mechanisms that govern the relationship of innovators to each of these spheres. Hence no one notion of intellectual property can clearly satisfy the distinct needs within each sphere. Appropriate policies must be carefully devised within such contexts, while recognizing the inter-relations among them. To be effective such policies must be developed with the participation of innovators, communities and stakeholders, and facilitated by institutional settings within which the systems operate. Beyond these general principles, a number of common concerns and approaches are worth addressing for dealing with intellectual property rights:

- Different scholars have argued for distinct rationale to protect knowledge in the public domain, community and individual innovators. Any IPR policy must address the impact and outcomes from subsequent changes in each of these spheres.
- Some form of intellectual property protection should not be considered the de facto solution for all problems related to access, compensation and dissemination of innovations.
- It is important to establish communal norms for access, usage and management of intellectual resources, preferably by developed and enforced by the community itself.
- It must be recognized that there may be different classes of rights and forms of access, usage and management of intellectual resources at distinct times for different parties.
- Compensatory liability schemes rather than exclusive property rights may be better suited for dealing with subpatentable innovations in particular industries.
- Institutional support and facilitation is necessary for innovations both from the industry and state as well as from the scientific community to provide legitimacy and enforcement.
- Networked technologies today both lower transaction costs for both illicit use and transfer as well as that of production and distribution. In addition online registries provide a global means to make all parties and intellectual claims more accountable. Hence, distributed networks and online databases can play a key role in shaping IPR today.

One can characterize intellectual property regimes along two main dimensions of the social arrangements that emerge (implicitly or explicitly) among participants:

A. *Sphere of Influence* (private, communal and public)
B. *Attributes of Social Contracts* (access, protection, liability etc) in each sphere

	Private	**Communal**	**Public**
Access			
Protection			
Liability			
Regulation			

We can examine how specific intellectual property regimes and mechanisms lineup in this typology such as GPL, Free GPL, Patents, Patent Pools, Copyrights, Trade Secrets, Compensatory Liability, and so on. Recognizing how specific systems deal with attributes of social contracts within each sphere of influence may provide greater insight into rethinking appropriate IPR measures and their effects. Note that this is a preliminary typology, additional attributes should be added based on the nature of system being examined and analysis desired.

This approach can serve as one of the analytic tools used to better understand the inter-related notions of IPR emerging from studies of collaborative design in online platforms like *ThinkCycle*. In summary, one needs to understand the complex nature of social incentives mechanisms, communal norms and intellectual property rights in the specific contexts of social and institutional settings, to develop models that support *cooperative innovation in the commons*.

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*[24] as well as simple online community publishing tools such as *Wiki Wiki Web*[25] or *Twiki*[26] that support editable webpages and *Movable Type*[27] for creating personal weblogs. While web-based design and modeling tools such as *PTC*[28] and *Dome*[29] 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*[30] run by the Free Software Foundation. Finally there are a number of community portals for knowledge exchange. The World Bank's *Development Gateway*[31] 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*[32] 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

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[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 "anthill 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 "anthill 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.

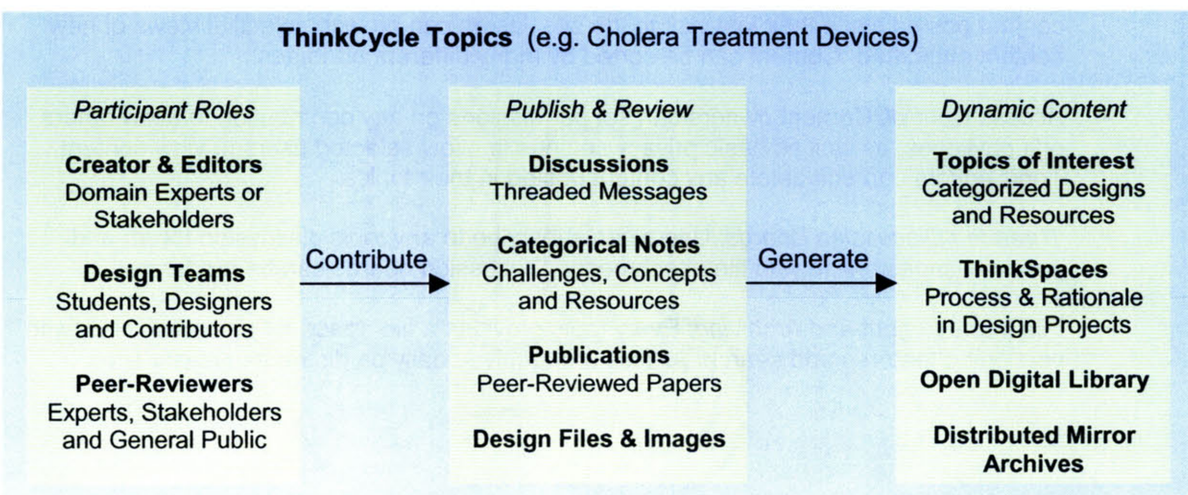

Figure 3.1: Knowledge sharing and collaborative design activities among diverse users on ThinkCycle.

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*.

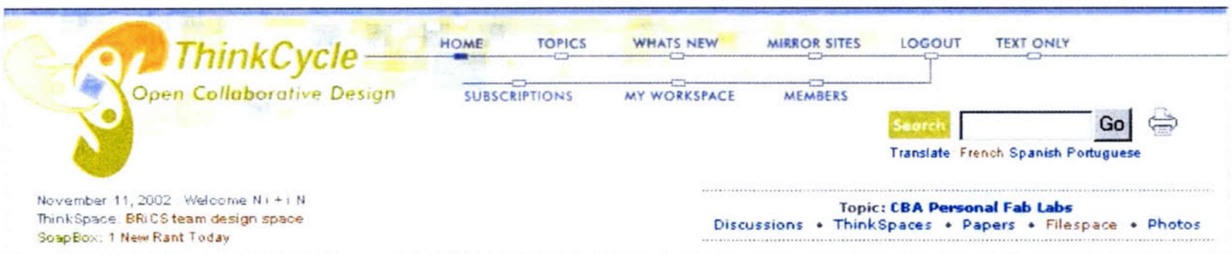


Figure 3.2: The navigational menu displays personalized information when members log in. The floating *Topic Navigator* remembers the Topic and ThinkSpace last visited and provides rapid access to all topic subsections.

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.

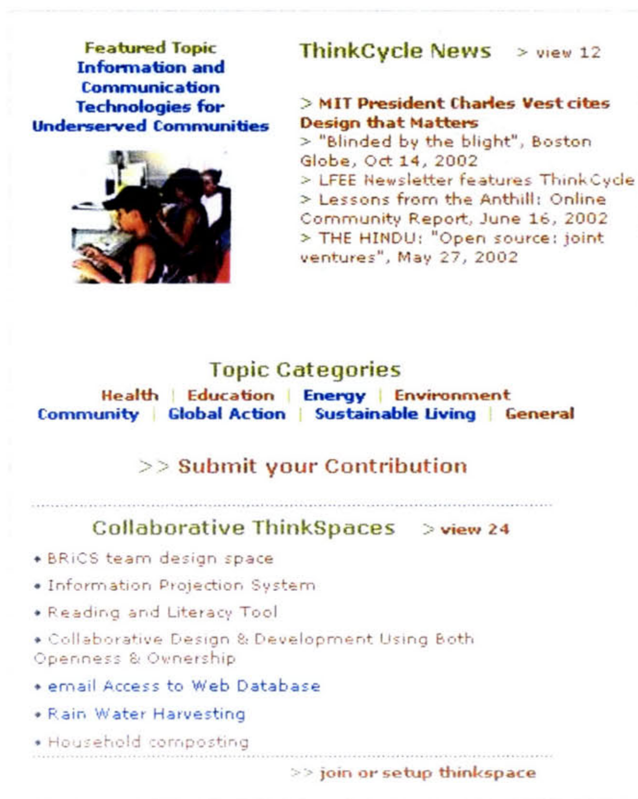
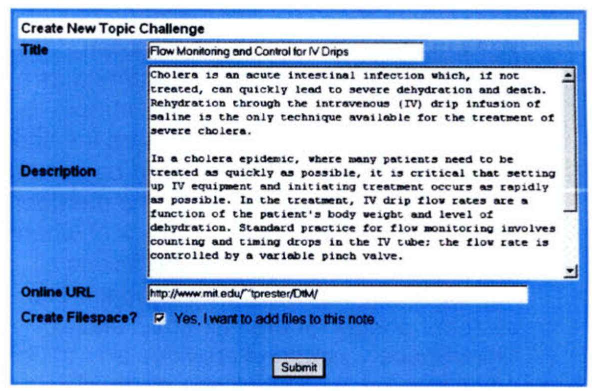


Figure 3.3: The front page shows the "Featured Topic" (automatically selected from recent postings) and new Topics, ThinkSpaces, concepts and challenges submitted.

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".

Figure 3.3: (a) "Rants" recently posted on the *SoapBox*. (b) Members active online and recent visitors. Also shows new postings since the last visit.

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.



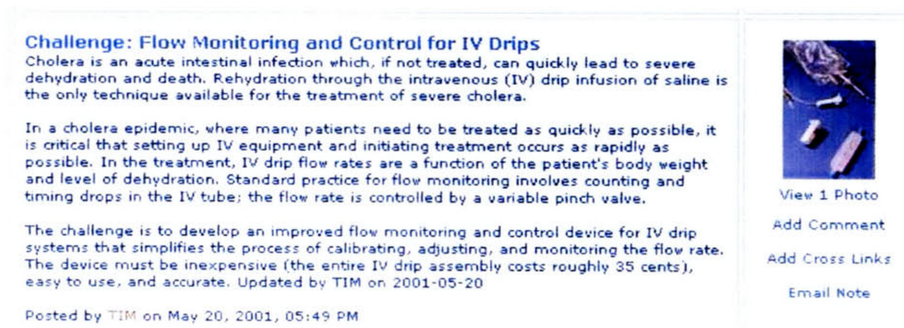


Figure 3.4: (a) The user posts a *challenge* in the topic on cholera treatment, which includes a summary, online links, files and images. (b) Members can add comments, cross-link the challenge to any topics or content posted on the site, and email it to others. The creator can provide access/control privileges to members.

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.

ThinkSpace: Premature Incubator Project

ThinkSpaces provide a shared space for members of design team to collaborate towards evolving design concepts. It serves as an informal online design notebook (or web-log) for each design team, with peer-review from others. Contribute notes and discussions here. Subscribe to get notifications whenever new notes are posted. ThinkSpaces can be restricted to specific members of the design team, by the creator. Any notes posted here can be shown on the Topic level if needed.

Design Team: Prasanga D. Hiniduma Lokuge, Rodney Jonace, Aileen Wu, Yael Maguire (DtM Instructor)

Summary: This project addresses the challenge of a passive premature infant incubator, posted on the thinkcycle website. We are in the process of assessing the current state-of-the-art in passive incubators, and aiming for a simplistic design for a robust and portable incubator. Our key client currently is a doctor from MSF, who has worked in related contexts in several third world countries. We have only recently commenced the full-speed design process.

Status: Project is in progress. Contacts/key informants: Need to get in touch with Doc from MGH. Currently in number crunching mode - Assessing heat and water loss from average premature infant in tropical conditions. Extrapolation of numbers to varying enviromental conditions: Birth weight analysis. Water balloon proxy feasibility analysis etc.

Created by Prasanga Hiniduma Lokuge on March 20, 2002, 01:47 PM Updated: 2002-03-23

Team ThinkSpace [Private Access]
Members (8) [Subscribe]
Post Message
messages (12)
View 25 files
Edit Summary
Permissions
Allow Public Access

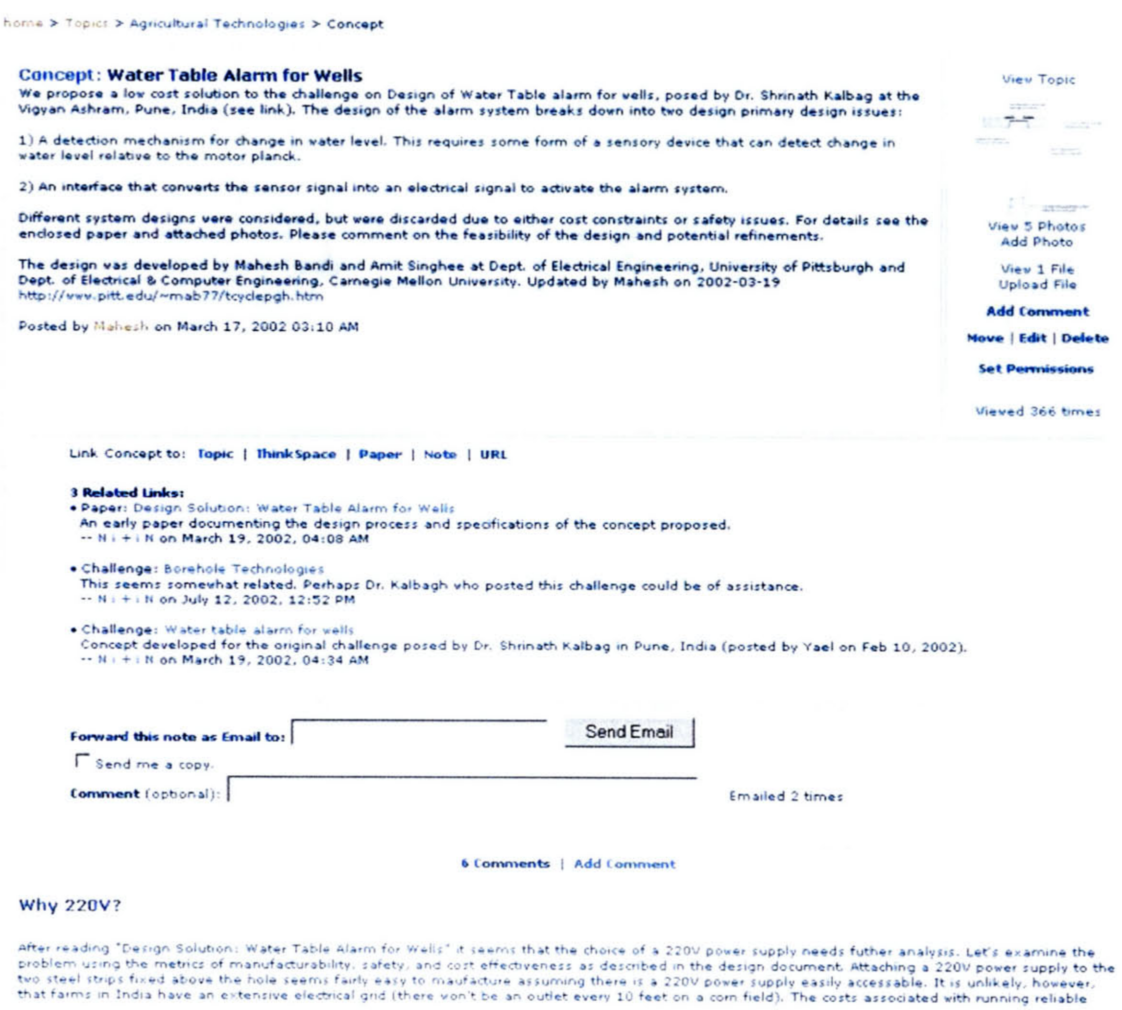
Post New Note | Notes Shown (3)

Concept: Collapsable, very low cost incubator shell

This is a simple tent design for an extremely low cost incubator. It was chosen for cleanability, durability and simple, compact transport. We have chosen the simplest design for a dome tent with square base that is self-tensioning and uses the smallest amount of materials. Unlike a tent which has poor insulation, three panels of the incubator will be double layered and filled with newspaper to minimize radiative, convective and conductive heat loss. The fourth panel will be a clear polymer providing physical and visual accessibility. This will help address the need for visible light to treat jaundice. Zippers are expensive and donÂ't form good seals, so a flap will be incorporated into this window. Inside the flap will be an inexpensive reusable adhesive such as static cling vinyl that will form an airtight seal to prevent heat loss. Updated by Yael on 2002-04-28

Posted by Yael on 2002-04-28

View 1 Comment
Add Comment
Add Cross Links
Email Note



home > Topics > Agricultural Technologies > Concept

Concept: Water Table Alarm for Wells

We propose a low cost solution to the challenge on Design of Water Table alarm for wells, posed by Dr. Shrinath Kalbag at the Vigyan Ashram, Pune, India (see link). The design of the alarm system breaks down into two design primary design issues:

1) A detection mechanism for change in water level. This requires some form of a sensory device that can detect change in water level relative to the motor planck.

2) An interface that converts the sensor signal into an electrical signal to activate the alarm system.

Different system designs were considered, but were discarded due to either cost constraints or safety issues. For details see the enclosed paper and attached photos. Please comment on the feasibility of the design and potential refinements.

The design was developed by Mahesh Bandi and Amit Singhee at Dept. of Electrical Engineering, University of Pittsburgh and Dept. of Electrical & Computer Engineering, Carnegie Mellon University. Updated by Mahesh on 2002-03-19
http://www.pitt.edu/~mab77/tcyclepgh.htm

Posted by Mahesh on March 17, 2002 03:10 AM

View Topic
View 5 Photos
Add Photo
View 1 File
Upload File
Add Comment
Move | Edit | Delete
Set Permissions
Viewed 366 times

Link Concept to: **Topic | ThinkSpace | Paper | Note | URL**

3 Related Links:

- Paper: Design Solution: Water Table Alarm for Wells
  An early paper documenting the design process and specifications of the concept proposed.
  -- N i + i N on March 19, 2002, 04:08 AM
- Challenge: Borehole Technologies
  This seems somewhat related. Perhaps Dr. Kalbagh who posted this challenge could be of assistance.
  -- N i + i N on July 12, 2002, 12:52 PM
- Challenge: Water table alarm for wells
  Concept developed for the original challenge posed by Dr. Shrinath Kalbag in Pune, India (posted by Yael on Feb 10, 2002).
  -- N i + i N on March 19, 2002, 04:34 AM

Forward this note as Email to: [ ] Send Email
Send me a copy.
Comment (optional): [ ] Emailed 2 times

6 Comments | Add Comment

Why 220V?

After reading "Design Solution: Water Table Alarm for Wells" it seems that the choice of a 220V power supply needs futher analysis. Let's examine the problem using the metrics of manufacturability, safety, and cost effectiveness as described in the design document. Attaching a 220V power supply to the two steel strips fixed above the hole seems fairly easy to maufacture assuming there is a 220V power supply easily accessable. It is unlikely, however, that farms in India have an extensive electrical grid (there won't be an outlet every 10 feet on a corn field). The costs associated with running reliable

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 scaleable 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*[41], 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
[43] http://www.thinkcycle.org/dyd02

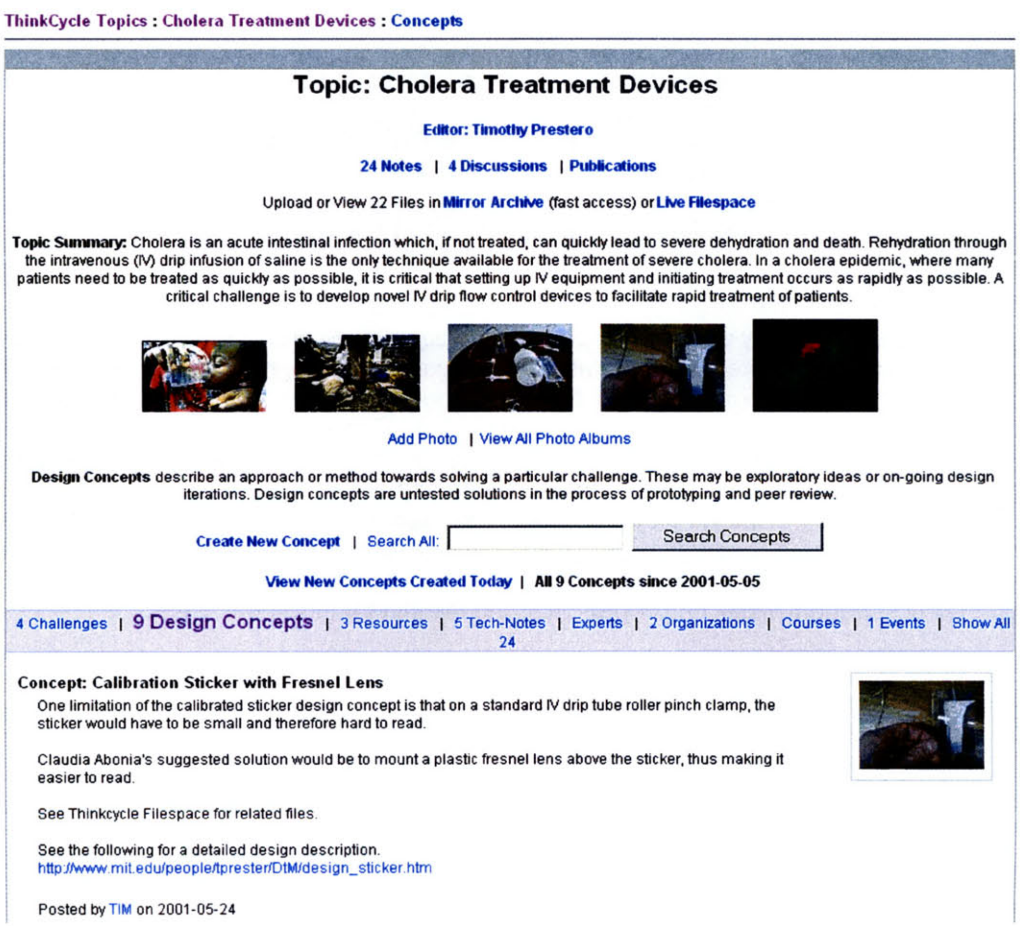


Figure 3.7: An earlier version of the ThinkCycle interface. a) Front page with new postings as well as recent topics and challenges, b) Topic section with different categories of notes shown; however the overall structure, spatial layout and information clutter was confusing for novices.

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[44] 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

Lets 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 inter-disciplinary 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.

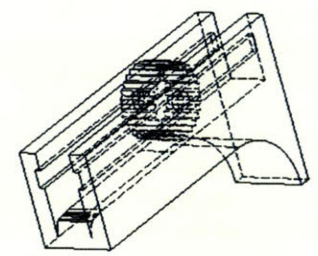


Figure 3.8: CAD drawing of the non-linear roller design

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

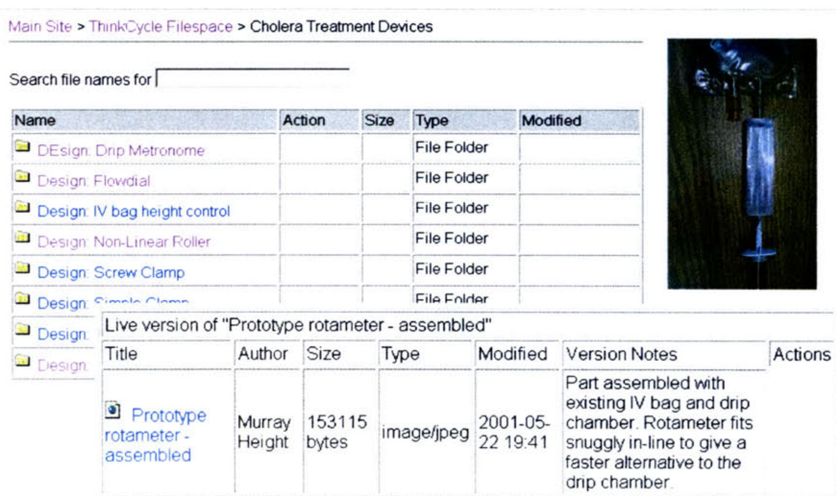


Figure 3.9: CAD models, images and documents gradually archived as files on ThinkCycle by members of the cholera treatment devices design team. The system keeps track of multiple versions of all files posted, as well as any necessary access permissions setup for each folder or file.

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.


Main Site > ThinkCycle Bboard > Cholera Treatment Devices

[Subscribe to Forum] [View Subscribers]

Messages [**Post a message**]

Subject	Author	Replies	Last update
Waste Management	Mike Lohse	0	05/31/01 02:43 pm
Summary: Dr. Ryan Interview @ MGH	Timothy Prestero	0	05/17/01 05:20 pm
To order	Yael Maguire	0	05/11/01 04:47 pm
Meeting Notes for Thursday, 08 March 2001	Timothy Prestero	0	05/08/01 09:10 pm

By Category

- DtM Health Group Meeting Notes (3)
- Uncategorized(1)

[Create a category]

Figure 3.10: A discussion forum with threaded messages among the team members and external participants. Meeting summaries were frequently archived here, while peers posted questions.

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[45].

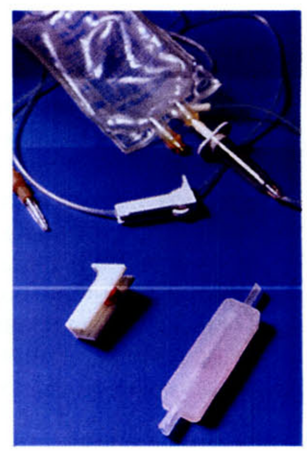


Figure 3.11: Final Rotameter prototype design with IV Drip

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.

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 inter-disciplinary 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.

4 COLLABORATIVE DESIGN AND LEARNING IN STUDIO COURSES

While software platforms can facilitate design collaboration, project-oriented courses in university settings can play an important role in developing and sustaining a culture of design innovation in critical problem domains. However, such courses require a multidisciplinary approach to learning and cooperative design. Over the last 2 years, along with other graduate students and faculty at MIT, I have been involved in creation and teaching of an experimental design studio, "*Design that Matters*". The studio course was run for the 2nd time in spring 2002, in conjunction with several similar studio courses at universities worldwide. To my knowledge few comprehensive studies of such learning and collaboration experiments have been conducted. Most experiments point to great challenges in the adoption and use of online tools in such settings for a variety of reasons.

4.1 Related Work: Online Collaboration and Learning in Educational Settings

With the proliferation of the Internet in schools and universities, there have been many attempts to integrate web-based collaborative technologies into educational curricula for more effective student learning. Three major initiatives at school and university levels are discussed here.

4.1.1 Learning and Collaboration in Schools

The *WEB project*[46] for online learning among students at rural Vermont schools has been underway since 1995, as part of a statewide initiative. School students and teachers used an online environment to post, discuss and critique student review of literary texts and projects in multimedia, digital art and music. From 1998-2000 an evaluation study was conducted by the RMC Research Corporation [Sherry02] to assess the impact of the project on nine cooperating schools, using quantitative data from surveys, qualitative data from site visits and triangulated with analysis of online student products. Site visits included interviewing teachers, students and focus group discussions with students. Online surveys were administered over a three-year period to all 165 teachers, administrators and online mentors. Student surveys measured a variety of student attitudes, motivations, behaviors and skill areas. 165 students high school and middle school participated in the surveys.

Student surveys indicated that about 95% students reported that they posted products and revised them at least once. Most students posted multiple times, however many final products were never posted. Participating teachers were involved in developing and benchmarking rubrics to assess student products. The pattern of results showed a number of trends: 1) When a new technology is introduced there is a learning curve that lowers performance before the desired student skills begin to increase again. 2) Teachers observed improvements in student behaviors over time, with engagement, constructive feedback and increased metacognitive skills earlier while higher-order thinking skills like depth in reports were observed only later. 3) Most teachers found it too early to tell about improvements in student grades and test scores. Self-reported measures of motivation indicated students tended to be more engaged in WEB project classes than in the school activities. Pre and post-test student surveys showed some improvement in application of skills, however a slight decline in class motivation (attributed to the timing of the survey at the end of school year). Interviews and focus groups showed students willingly spending many hours learning and applying new skills, motivated by the technology rather than demands of the instructor. Students were found to be evaluating and improving their work. Student product assessments conducted by 143 teachers and juried by experts showed students nearly met pre-set standards for design and revision of the products they created, however no significant improvement was observed. The greatest challenge in such studies has been to establish clear linkages between educational technology and student achievement.

4.1.2 Nature of Collaboration in University Courses

Online tools for effective project-based learning in university settings have been developed and studied for a number of years at the College of Computing and the EduTech Institute at Georgia

[46] http://www.webproject.org

Tech. A succession of experiments on collaboration technologies and their introduction in classroom settings provide a mixed picture, highlighting some successes, but many failures and challenges in adoption and sustained usage by students. Team planning and facilitation tools such as *CaMILE* introduced to sophomore computer science and mechanical engineering students, showed poor adoption, usage and minimal content postings [Kehoe98]. Surveys and interviews indicated that students saw little benefit in the computer-supported tools, particularly when students already had a close working relationship with teammates. However, subsequent web-based versions of these tools allowed linking notes to threads in online discussions, producing longer threads vs. that of the same class using newsgroups (unanchored threads). Hence, a form of "anchored collaboration" supported in web-based tools encouraged extended discussions, which could contribute to learning.

CoWeb[47] is a collaborative learning environment used in many classes at Georgia Tech [Guzdial02]; it is developed as a simple domain-independent collaboration tool that allows users to create editable webpages and embed online links or uploaded files. With minimal privileges, controls or user tracking, all users had equal access to add or change any existing content submitted to the site and ability for anonymous posting; one professor referred to it as a "whiteboard that everyone can write on". However, all versions of the webpages are archived and can be restored when needed. CoWeb has been applied in nearly a 100 courses at Georgia Tech in domains such as architecture, computer science, engineering, mathematics and English. The tool seems to have been more readily adopted in English composition and design-oriented courses such as architecture studios, while there has been active resistance in engineering, mathematics and computer science courses. Evidence from interviews and questionnaires points to a number of sources for both support and resistance observed in different learning contexts.

4.1.3 Collaboration in Architecture Studios

CoWeb was employed in an architecture studio to encourage students to post and explain their designs online, facilitate access to online cases/resources, support peer-review and feedback from distant critics [Zimring01]. Students in the studio were assigned the same design problem, five chose to work in two-person teams while five others worked independently. Six professional critics were invited to participate, most of whom where geographically separated from the students. Students were asked to use CoWeb to create web pages with scanned drawings and text describing their ongoing designs concepts. They were also initially asked to create online journals with a record of considerations, evaluations, discussions, ideas and so on, easily accessible to all, so that the virtual critics could regularly comment on it. However, the researchers found that "casual interaction was not prevalent". It was noted that the initial stages of design involved a flurry of ideas that were rapidly evaluated; when students put their thoughts in the journal they became too long and scattered, and most students were reluctant to commit initial conceptions publicly or take the effort to scan and upload all early designs. Most students eventually created online presentations (for the 3 formal reviews scheduled in the term) as linear narratives rather than add hyperlinks or organize them with multiple web pages in a nonlinear manner. Due to the effort involved in setting up online presentations, most were not continuously updated throughout the term; this meant that some of the design decisions made between presentations were left undocumented.

Critics experienced long delays downloading large documents on dialup modems. They preferred to understand the overall design context and products, rather than comment on early and changing design concepts. Most comments posted were encouraging; sharp criticism was never posted. Students did not always find the comments relevant as they had already moved on to other issues in their designs, by the time the comments were posted. Some critics complained that they were not sure their comments were "heard" as questions were never answered and there were long delays between student postings. Many students preferred to send critics email to describe details or seek specific advise. Most students did not post comments on each other's designs online, either because they were not explicitly instructed to do so or they provided

[47] http://coweb.cc.gatech.edu/csl

feedback to each other verbally, or their interest simply diverged over the term. They may not have seen a clear instrumental or learning value in doing so. Another reason cited was to do with the notion of "ownership" of the online projects, reinforcing a perceived distance among projects and freedom to comments on other's online space. Structured reviews regularly scheduled were found to be effective, rather than unstructured online critiques. However, critics appreciated the ability to review and interact asynchronously on their own time, having the opportunity to consult material, prior work and carefully organize their comments before posting. Overall, the task of presenting design concepts in an online environment, forced upon students to continuously evaluate and revise their work, serving a critical role for better reflection and maturity of ideas.

4.1.4 Lack of Collaboration in Science/Engineering Courses

The adoption and use of CoWeb in some courses has shown a surprising active resistance to online posting and collaboration, particularly by science and engineering students [Guzdial01]. A number of interesting and sometimes perplexing behaviors were observed: In a experiment with students working on a joint problem in two mathematics and chemical engineering courses, 40% of the mathematics students accepted a zero on the assignment rather than collaborate with chemical engineers. In one 10 week semester, students in an architecture class generated over 1500 web pages while in the chemical engineering course, not a single student posted anything online; in a computer science course of 340 students only 22 students participated. In a mathematics course, even though researchers developed an online equation-editing tool, despite faculty encouragement not a single student ever tried it. The researchers feel that these trends indicate that it was neither the technology nor a lack of understanding of how to collaborate; if it were so there would have been evidence of students at least trying the technologies. But there seems to be an active resistance to the notion of collaboration itself, which explains these results.

In questionnaires and interviews researchers found that students often viewed the class or field as intensely competitive, while demanding a great deal of time and effort. Students "didn't want to get railed" i.e. receive critical reviews and mentioned "with the curve it is better when your peers do badly". Students often perceived that there was "only one correct answer" to homework problems even when faculty insisted it was not true. Hence, in such highly competitive courses, students found it only "rational not to collaborate or help others", while those in design or English composition courses with open-ended and ill-structured problems tended to have greater group interaction, as demonstrated in earlier studies [Cohen94]. Researchers make several recommendations to encourage peer review, learning and collaboration in science and engineering courses: 1) explicitly encouraging group discussion and activities e.g. promoting debate around problem formulation, 2) gradually introducing collaborative tasks, initially with low-commitment, and 3) rethinking academic incentives such as course structure and grading.

4.1.5 Collaborative and Experimental Social Design Studios

Faculty at Carnegie Mellon University and Technical University of Delft, Netherlands taught joint courses in fall 2000, addressing problem formulation and product design with real-world projects and industrial partners [Subrahmanian01]. Assignments included design problems such as transportation systems for Pittsburgh and water/sewage treatment systems for Amsterdam. Shared lectures were organized through video exchange. Each week, students in both campuses were asked to present reports on related readings and their design solutions, communicating electronically (phone, email and chat). Students used LIRE[48], an online document management system developed at CMU, which provides access control, notification, linking and search. During the course 25-30 students worked in 5 interdisciplinary teams, gave progress reports each week, and were each asked to present one lecture on design methods. Faculty and students were enthusiastic about the course, considering it valuable to collaborate with students having different perspectives and a preparation for future real-life scenarios. Though the course seems to have been successfully initiated, no formal evaluation has been conducted or reported in published

[48] http://www.ndim.edrc.cmu.edu/papers/lire.htm

papers. The *Design that Matters* studio courses took a somewhat related approach and show many similar challenges in design collaboration, which I now highlight in the study I conducted.

4.2 Study of Collaborative Design and Learning in the MIT Design Studio

In the context of the MIT Design that Matters Studio, I initiated a three-part study that assesses the nature of collaborative design, learning outcomes and social attitudes of students, external participants and instructors towards cooperative initiatives, using online usage, questionnaires and interviews. The pilot study was conducted primarily at MIT in May-July 2002 and will be extended to participants in the studio course taught in Bangalore, based on preliminary results and refined methods. The study consists of online surveys, interviews, and case studies of design projects. This section reports on the first stage of the study involving the online survey. The summary of survey responses provides a partial qualitative assessment and preliminary understanding of key issues in learning and collaboration that were further probed in the intensive interviews conducted subsequently.

The survey was completed by 17 students who participated in the Spring 2001/2002 studio courses at MIT. The survey responses provide a preliminary and qualitative assessment of student attitudes towards learning and collaboration in this setting. The responses suggest a number of key themes for studio courses: 1) courses focusing on sustainable design through hands-on learning have a broad appeal among students, 2) an important element of such real-world design courses is establishing meaningful linkages with external domain experts and organizations, and providing students opportunities for fieldwork, 3) the success of such courses requires commitment from faculty to provide academic legitimacy and active involvement of instructors and domain experts in mentoring group projects.

For online collaboration platforms, the responses indicate: 1) online tools focusing on sustainable design are useful for sharing and archiving designs, and have a role in dissemination and problem solving however they are most valuable when teams or domain experts are not always co-located, 2) the overhead for usage by busy engineering students must be minimized by simplified interfaces and greater integration with existing channels of communication like email, 3) in addition to improved navigation, many users requested tools for *asynchronous content updates* and *real-time chat*. Overall responses suggest that users view design as a *social process* rather than only that of archiving and exchanging data.

4.2.1 Goals of Online Survey

For the online survey there are two main objectives:

A. Examine Nature of Collaborative Design Projects in Classroom Studio Courses
   I. Background and prior experience/inclination towards collaborative design.
   II. Process, artifacts, tools and procedures used in ongoing design activity.
   III. How did they research, document, and negotiate design constraints?
   IV. How was peer-review solicited and influence design outcomes?
   V. Concerns about intellectual property, privacy or disclosure of design.

   Key Parameter of Interest: Social Process of cooperative design and incentives for open disclosure and review?

B. Examine Online Participation and Design Activity on ThinkCycle Platform
   I. Prior familiarity, access and experience with online interaction.
   II. Incentives to post content online, regularity and nature of postings.
   III. How did online posting and peer-review influence design process/outcomes?
   IV. Barriers and constraints experienced that limited online interaction.
   V. Tradeoffs in the mapping of natural design activity to online interaction.

   Key Parameter of Interest: Why do we see a low level of adoption and online activity by participants in collaborative design projects? What are the barriers involved?

Note: all assumptions and outcomes are based on a small group of design projects in a university setting and the use of an experimental online collaboration platform.

4.2.2 Methodology of Online Survey

The online survey consists of a questionnaire to solicit self-reported background, motivations and experiences in the design studio and online platform. The survey uses a mix of multiple-choice questions and open-ended questions. For many multiple-choice questions a *Likert scale* was used to provide a series of statements to which participants can indicate degrees of agreement or disagreement. The survey consists of 80 questions categorized into 5 sections: 1) demographic information, 2) general attitudes towards collaboration in courses, 3) evaluation of studio design courses, 4) online access and experience and 5) experience and usage of ThinkCycle.

The survey and interview protocols were submitted to the MIT Committee on the Use of Humans as Experimental Subjects (COUHES), in accordance with the following guidelines[49]:

> *"Questionnaires distributed and interviews conducted for research purposes are subject to COUHES review. Questionnaires must state at the beginning that answering is voluntary and that there is no obligation to answer every question. There must also be a statement about confidentiality and anonymity. Interviewers must assure their subjects of the same rights and the right to discontinue the interview at any time."*

The COUHES committee met on May 16, 2002 and reviewed the study proposal. The survey was revised to incorporate their suggestions, and was subsequently approved by the committee.

A survey questionnaire generation, administration and reporting system has been deployed on ThinkCycle. I have developed a comprehensive survey tool that allows investigators to setup online surveys with questions having multiple response options. All user responses are stored in the Oracle database in a secure manner. Cumulative survey results are automatically generated and displayed using graphs and anonymous text summaries.

The survey was pilot tested with one participant and refined before making it available to all other participants at MIT. All participants signed an informed consent form and most completed the survey in 30-45 minutes. All responses are anonymous and cumulative results automatically generated online are only released to participants who have already completed the survey.

4.3 Examining the Results of the Survey Evaluation

The following is a summary of responses from the online survey administered to students that attended the MIT studio design courses in 2001 and 2002. The summary is categorized into 5 sections (along the lines of the survey), with key survey results outlined and some preliminary interpretations of these results.

4.3.1 Demographic Information

Summarized results from the first section of the survey indicate:

- ***Response Rate:*** The online survey was completed by 17 respondents out of 18 participants solicited from the MIT DtM studio courses in 2001 and 2002 (94% response rate). Despite 80 questions asked in the survey (multiple-choice and open ended), there was a completion rate of 97-100%.

- ***Demographics:*** Of the 17 participants roughly 70% were male and 30% female with an average age of 28 years (standard deviation of 10). The participants were equally

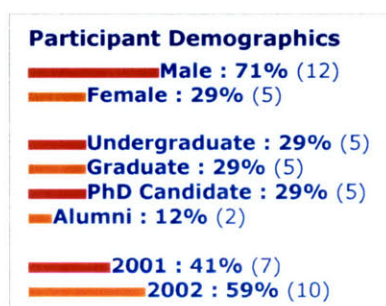


Figure 4.1: Participant Demographics

[49] http://web.mit.edu/committees/couhes/consent.htm

split among undergraduate, graduate and PhD candidates (nearly a third each) with a small number of alumni attending (2 respondents).

- ***Background:*** Almost all respondents were MIT students and had technical backgrounds. Degree majors included a diverse mix of engineering fields (Mechanical, Chemical, Aeronautics, Biomedical and Oceanographic) along with some students from the Media Lab and one in humanities (English and Business from Harvard).

Diverse but Typical Student Mix: The overall demographics provide a range of respondents among undergraduate and graduate students with diverse technical backgrounds across MIT. The age and gender of respondents also suggests a fairly typical distribution found in advanced MIT courses.

Broad Course Appeal: The demographics of participants observed suggests that the studio course has appeal to a broad mix of engineering students throughout the university, rather than in any one discipline alone. This indicates that there would be student interest for such a course, offered institute-wide and/or incorporated in many engineering curricula.

Small Class Size: One may consider the students participating in the studio courses each year (9-12) to be a low number relative to standard MIT courses – this can be assumed to be either due to lack of publicity, novelty of the subject, lack of legitimacy (due to unofficial status of course) or lack of perceived integration into existing engineering curricula. On the other hand, the number of students participating each year may be considered entirely appropriate for a studio design course (offered for optional credit) not unlike seminar or special topics electives offered at MIT. However, there are indications (discussed later) that many more students would have participated if they had known about the studio course well ahead of time.

Survey Response: The high survey response rate and completion rate suggests enthusiasm to participate in the study. One student from the 2001 course reviewed the survey questions but declined to participate, despite my insistence. He explained that he felt a lack of confidence that his project and learning experience was successful enough to report in the survey.

Note on Survey Response: Overall, one must recognize that the total number of respondents available for this survey does not by any means provide a representative and statistically significant sample for rigorous quantitative analysis. Hence, the results gleaned from respondents in this survey (within the context of a small studio course offered at MIT) must be interpreted qualitatively to suggest potential behaviors and hypothesis for future studies on a larger number of courses and participants. These summary results are also useful for posing relevant questions in follow-up interviews with some of these participants, to better understand individual behavioral attitudes and motivations.

4.3.2 General Attitudes towards Collaboration in Courses

In this section of the survey, general attitudes towards collaboration were solicited before asking more specific questions in the context of the actual design studio and usage of ThinkCycle. The responses indicate a number of general attitudes (based on cumulative results):

Individual vs. Group Work: Questions 1 and 2 were setup to disambiguate preference vs. benefit of working in groups. It was expected that some students would consider group work beneficial, yet prefer to work alone for various reasons. In the survey 71% of the respondents disagreed that they preferred to work independently, while 100% indicated they found working with others more helpful. 94% also indicated that they found their last group experience enjoyable and worthwhile.

The high rate of positive attitudes towards the notion of group work (or collaboration) is not necessarily surprising, but serves as a notable point as we examine to what extent did students *actually* work in groups over the course of the design studio, and how much did they benefit from such collaboration. This also bears on the level and nature of online interaction, sharing and peer review that one might expect to see among these students using ThinkCycle.

Perceived Barriers for Open Sharing of Design: The survey examined three specific perceived barriers to sharing – competition, maturity of ideas, and effort involved.

Role of Competition: Question 4 was used to determine if perhaps the *perceived* competitive nature of a field might induce lower incentive among students to collaborate or share evolving designs openly (within and outside the class). 42% of the respondents viewed the field of their design project as intensely competitive.

One must note that most students did not take the course for credit; hence there would have been little academic competition to receive better grades. Later in the survey, only 12% felt the course to be intensely competitive among students taking it. However, as the projects may have impact in real-world settings, some students may perceive a level of external competition. Question 5.A. also solicits a response to whether students may not share openly due to such competition. However, only 12% of the respondents were concerned that they would not share project designs openly because others may use their ideas without benefit to them.

1. I prefer to work independently on design projects rather than in groups.

Agree: 24% (4)
Neutral: 6% (1)
Disagree: 53% (9)
Strongly Disagree: 18% (3)

2. Working with others on projects is more helpful than working alone.

Strongly Agree: 59% (10)
Agree: 41% (7)

3. The last time I was involved in a group project, I found it to be an enjoyable and worthwhile experience.

Strongly Agree: 82% (14)
Agree: 12% (2)
Neutral: 6% (1)

4. I view the field of my design project as intensely competitive.

Strongly Agree: 24% (4)
Agree: 18% (3)
Neutral: 47% (8)
Strongly Disagree: 12% (2)

5. I don't want to share my project designs openly because:

A. Others may use it without much credit or benefit to me.
Agree: 12% (2)
Neutral: 53% (9)
Disagree: 29% (5)
Strongly Disagree: 6% (1)

B. My ideas are too premature for others to review.
Strongly Agree: 12% (2)
Agree: 12% (2)
Neutral: 6% (1)
Disagree: 59% (10)
Strongly Disagree: 12% (2)

C. It takes too much effort.
Agree: 24% (4)
Neutral: 24% (4)
Disagree: 41% (7)
Strongly Disagree: 12% (2)

Figure 4.2: Attitudes towards collaboration.

Maturity of ideas and effort involved: It was expected that many respondents would feel uncomfortable sharing premature ideas, however only 24% perceived this as a barrier. Similarly only 24% felt it took too much effort to share project designs openly. Overall it seems that 76-88% felt that none of these three factors prohibited them from openly sharing their project designs. Hence we need to carefully understand why the respondents later do not actively seem to share their designs online at a level that one would expect.

4.3.3 Evaluation of Studio Design Course

In this section participants were asked to reflect on their experiences with the studio design course they took at MIT. The section consisted of 24 multiple-choice and 4 open-ended questions. Of the respondents 41% took the course in 2001, where as 59% attended the 2002 course.

Why students took the Design that Matters Studio Course? 4 main reasons cited:

- Exposure to real-world problems and globally relevant social/developmental issues.
- Opportunity to work on practical design projects and learning by doing.
- Access to technical resources, a simulating environment and learning with peers.
- Lack of similar design studios in their own curricula or means to address social concerns.

General Evaluation of Course

Regarding the outcomes of the course, 71% agreed that the course exceed their expectations of learning, 88% felt it changed their approach to socially-conscious design, 82% felt it provided them with valuable experience and real-world skills, and nearly all respondents (94%) mentioned that it gave them a good understanding of real world problems and challenges.

Relative to other project-based courses taken, 64% of the respondents felt that they learned more in this design studio while only 25% found it more difficult and 38% found it more time consuming.

It must be noted that there could be a slight bias in the reporting by respondents as the survey was administered by a course instructor (though responses are anonymous). However in open-ended questions later in the survey, most respondents did not shy away from critical feedback.

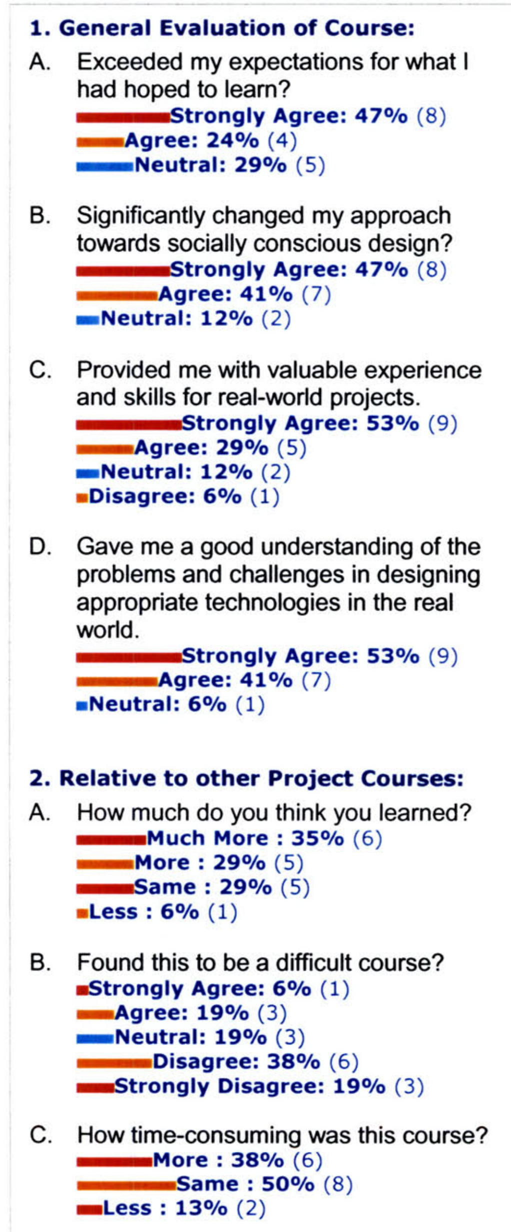


Figure 4.3: General evaluation and comparison with other project-based courses.

One interpretation of the responses points to the fact that the material learned in the course and through the design projects is not significantly covered or available in other courses at MIT. This points to a compelling need for offering similar design studios among many departments and enhancing existing curricula to incorporate elements of socially conscious or sustainable design. It may also indicate a greater level of learning through exposure to real-world problems, practical projects and peer review.

Beneficial Role of Guest Speakers, Domain Experts and Peers: In the survey, 95% agreed that guest speakers were engaging and insightful (71% agreed strongly). 76% found their interaction with external domain experts to be productive, while 65% agreed that peer reviews and collaborations were helpful towards their projects. Finally, 88% found the course instructors to be helpful in teaching and mentoring projects (53% strongly agreed). Hence, the diverse participants involved have a valuable role in the success of such a studio design course, particularly one with such a real-world focus.

Experience with Design Projects:

How did students find design projects?
4 main approaches for finding projects:

- Prior interest in a specific problem or area (35%)
- Through joining other classmates (28%)
- From challenges posted on ThinkCycle (17%)
- Speaking with a domain expert (11%)

The instructors had expected that the majority of projects would be selected from the online database, however it seems that personal interest and domain experts have an important role to play in providing ideas or motivation towards projects. It also indicates that instructors must recognize that many people will simply prefer to join others in well defined projects, rather than soliciting their own; this suggests instructors make a greater effort to steer students towards compelling projects and teams.

Who contributed the most to the projects?
71% of the respondents felt that over two people contributed to the project. Since most teams consisted of no more than 3 people, this suggests the role of external peers, domain experts and mentors in such design projects. 53% felt that their team members contributed the most while 29% felt they themselves were the primary contributor.

Time Spent on the Course and Projects:
77% of the respondents attended the majority of the course sessions and most spent at least 3-5 hours per week on their projects outside class. 88% agreed that they wish to continue working on their projects after the course is completed. This suggests that participants feel personally motivated to engage in their projects, regardless of the requirements of the course (note that most students did not take this course for credit).

Perceived Impact of the Projects:
Most respondents agreed that their projects had great potential for critical social impact (59% agreed strongly), while only 36% agreed that their projects had monetary value in the real world. Hence, a key motivation driving students was the perceived social impact of their work, rather than course credit or potential monetary incentives.

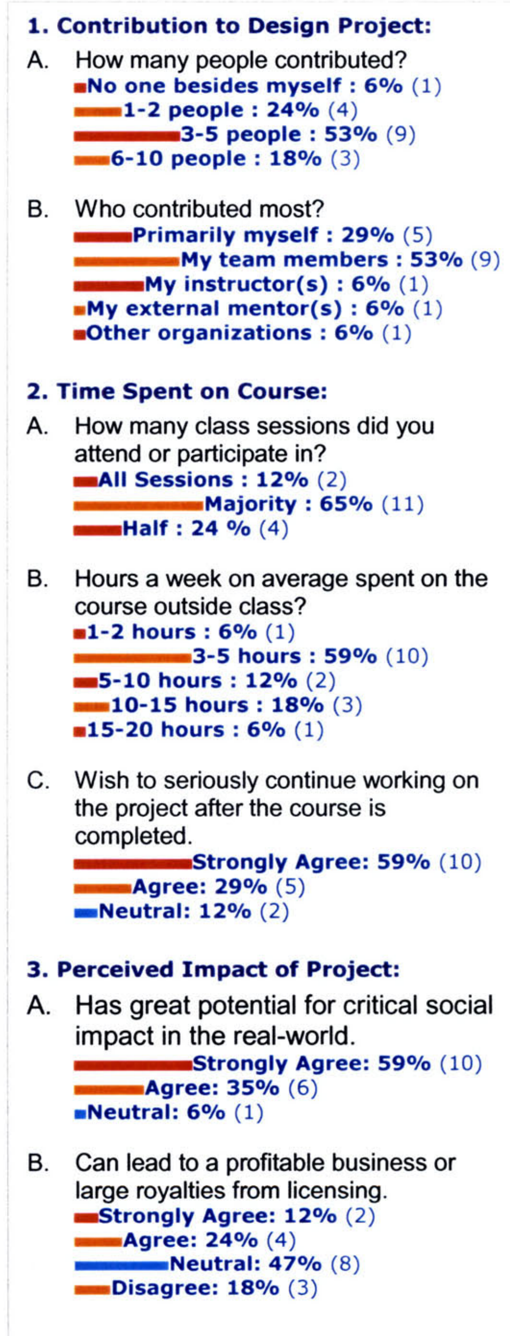


Figure 4.4: Experience with design projects – perceived impact, time spent and contributions.

Best Outcomes of the Course Reported by Students
Summarizing the best outcomes mentioned by respondents: (in no particular order)

- Meeting accomplished practitioners, instructors and like-minded people in the field.
- Awareness and appreciation of problems faced by communities in developing countries.
- Learning social aspects of design and broader social issues in development.
- Collaboration with motivated students across different disciplines.
- Seeing a concept idea develop to a working prototype that tackles a real-world problem.

- Recognizing technical, social and political challenges in bringing products to market.
- Winning top awards in design competitions or receiving patents from course projects.

Suggestions for Improving the Design that Matters Studio:

People

- Engage a network of faculty members at MIT (working in related areas) to be more involved in the course or actively supervising projects.
- There should be more instructor involvement with projects. Make sure mentors assigned to projects are actually available to work with the teams.
- Make more time available with external domain experts and speakers and less frequent in-class critiques (valuable but repetitive when progress on projects was slow).
- More emphasis and assistance with connecting to organizations that offered design challenges. Have field visits perhaps prior to beginning of class.
- Enhance access to final users of the design project, to get better feedback and iteration.
- Initiate social events and create more class spirit to encourage students to mix socially, and feel part of a supportive community.

Tools and Resources

- Easier to use tools for collaboration – posting and browsing was not as fluid as expected.
- Setup a library of source material accessed by students over time, to benefit future students.
- Make tutorials available on various subjects such as programming, electronics etc.

Course Structure

- The course should be offered for credit so that students may spend sufficient time on projects instead of hurting their academic time. In one survey question, 94% of the respondents (82% strongly) recommended the course be offered for credit to all students as part of the university curricula. However, one student disagreed, as she felt it should not be required unless people actually have an inclination to work on socially conscious design projects; her reasoning was "to ensure students who register, do so because they are serious and passionate about the topic."
- There should be a more concerted effort to publicize the class campus-wide, as many students would have liked to take it had they known about it sooner.
- Better organization in the required readings and the class assignment schedule.
- Some undergraduate students suggested the course be more structured and lectures better organized e.g. "Sometimes class sessions seemed like they were strung together without much thought beforehand". Graduate students preferred the open-ended format.

Course Content

- A more serious commitment to ethnographic research before design; many projects would benefit greatly from that.
- Investigate broader scope of projects including political, social and economic models (particularly in non-profit settings).
- Instruction on Media Lab machines and tools earlier in the semester.
- Have video footage of challenges available for students to review; it is more appealing and compelling than verbal descriptions on the website.

Design Projects

- Encourage more team building to make people comfortable to share their thoughts and visions without feeling ridiculed.
- Assign groups based on problem domains of interest and ensure diversity by mixing people with different skills, instead of waiting for groups to form naturally.
- Enforce stricter rules about project deadlines.
- Spend more time in the beginning discussing potential projects in class, rather than expecting students to find projects on the website or on their own.

- Instructors should do some background research on potential projects and initiate contact with domain experts, and present well-posed projects at the beginning of the term. This will allow students to get started with projects sooner.

4.3.4 Online Access and Experience

In this section, participants were asked about their access and exposure to the Internet and collaborative technologies.

Good Internet Access and Experience: The responses indicate that nearly 90% of the respondents considered themselves proficient with the Internet and had fast access. All respondents browsed the web and check email several times a day, while many occasionally used online chat. Hence, lack of access or experience is less likely to be a factor in explaining the nature of online interaction for the participants at the MIT design studio.

Regular Usage of Different Online Modalities: Comparing different modes of access, email and web usage appears to be similar, while there is a wide distribution of how often some users use instant messaging (daily or weekly). Over 50% do not use instant messaging. Understanding modes of access is important to recognize the ways in which people work and naturally communicate with others on a regular basis. These patterns would suggest that collaborative tools for sharing ongoing design, must also integrate with such modalities in different ways. For example, some participants may prefer to receive email notifications and upload designs via email, instead of using the website. Some may wish to use an instant messaging channel to discuss design instead of using online discussion forums on the web. Though the survey responses in this section suggest some rough trends, detailed responses later provide greater evidence towards this hypothesis.

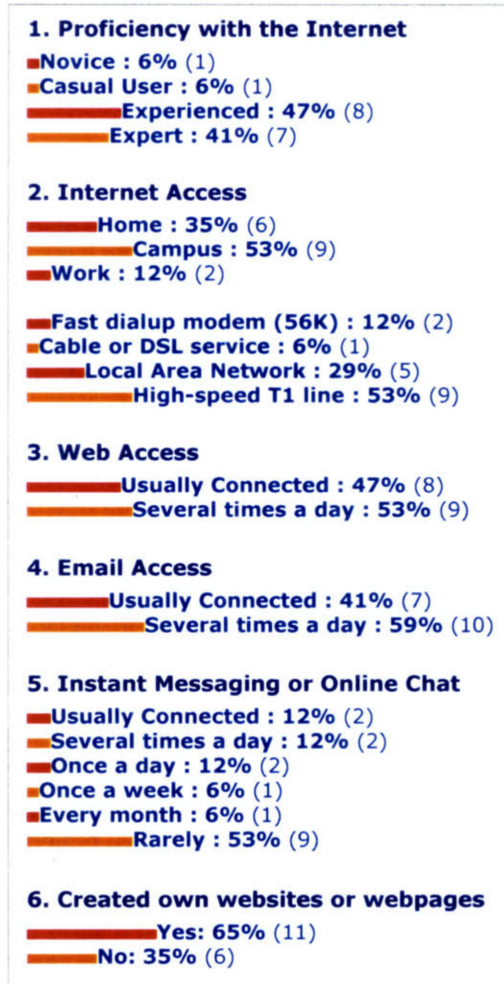


Figure 4.5: Online access and experience.

Lack of Experience with Online Collaboration?
Among the respondents, 65% had previously created their own websites or webpages. In an open-ended question, most respondents mentioned that they used web-authoring tools such as Microsoft Front Page or Macromedia Dreamweaver, while a few indicated they hand-coded html themselves. Regarding collaboration tools, only one person mentioned tools such as Net-meeting, Chat and Cu-SeeMe and another mentioned using Swiki (shared web-authoring). Most respondents did not indicate any prior experience with online collaboration tools, besides using ThinkCycle. It is entirely possible that they have indeed used such online tools, but simply did not perceive them as being "collaboration tools". Given their primary backgrounds in engineering (vs. computer science) where much of their design activity is hands-on and face-to-face, many of these respondents may not be naturally inclined to using collaborative software tools like ThinkCycle, particularly on a regular basis in design courses. Hence, the notion of online collaboration itself may be considered a novel activity for most participants. Detailed survey responses in the next section point to similar attitudes. This indicates a greater need for familiarizing students both with online tools and collaborative processes early in the term, and finding ways to make online sharing a natural part of their design activity.

4.3.5 *Experience and Usage of ThinkCycle*

In this section participants were asked to reflect on their experiences with the ThinkCycle online collaboration platform, used during the MIT design studio. The section had 15 multiple-choice and 13 open-ended questions.

Figure 4.6: ThinkCycle usage and usability.

In summary, all respondents indicated that they had used ThinkCycle during the course. Of the respondents, 59% visited the site at least several times a week and 82% believed it is a useful online tool. However, the frequency of postings was much lower than expected (only 31% posted content several times a week). In terms of general usability, 53% found it complicated and confusing and 30% found it very time-consuming to use.

Lets consider the responses in more detail to better understand behavior and attitudes towards online collaboration and the ThinkCycle platform. A key question is - *What prevents participants from using an online tool such as ThinkCycle more actively?* The poor usability of the tool, unfamiliarity with online collaboration, lack of perceived value of engaging in online interaction or simply a lack of time in a demanding project-based course?

ThinkCycle Usage

As part of the Design that Matters course, all students were expected to post project-related content on ThinkCycle on a regular basis; we expected that most would browse the site every week and post content a few times a week to maintain an updated project archive and solicit feedback. The survey indicates that only 18% of the respondents browsed the ThinkCycle site everyday, while 59% visited several times a week. A critical point is that only 31% posted content on the site several times a week. The question is what sort of content was frequently posted and why? What prevents more active usage of the online site? Aggregate statistics and individual usage data are logged in the ThinkCycle Oracle database, and can be analyzed further if needed. In the survey we primarily try to examine individual attitudes and perceptions towards online collaboration (rather than precise daily usage), particularly in the context of ThinkCycle.

ThinkCycle Usability

53% of the respondents found ThinkCycle complicated and confusing to use, while 30% found it very time-consuming. It must be noted that only 2 respondents (12%) had previously mentioned any prior experience with online collaborative tools. A tutorial on ThinkCycle was made available to students at the beginning of the spring 2002 term. Hence, in the survey 59% of the respondents (10 students) who took the 2002 course had access to the tutorial, and 60% of those (6 students) reviewed it. Half of the respondents that reviewed the tutorial in 2002 found it useful, while 53% of all respondents found it necessary to ask instructors or peers on how to use

ThinkCycle. With this basic summary of the responses on usability we will later consider detailed responses to better understand the key reasons preventing more active online interaction.

Perceived Contribution of ThinkCycle
Most respondents (83%) agreed that ThinkCycle is a useful online tool (47% felt strongly). 77% agreed that using ThinkCycle contributed towards their design projects. Finally, 82% felt that they would like to use an online collaboration tool for design projects in the future. Hence, there is a perceived useful role for such online tools in design, however for a number of reasons participants did not fully utilize and engage with the online platform in the studio courses, though they still found it beneficial in their design projects.

More specifically, 70% found viewing and searching content on ThinkCycle useful vs. 57% found posting content useful. In terms of reviewing content, a slightly lower number (44-51%) found both posting reviews and comments from others equally useful. Based on the these responses, the main useful aspects include:

1. An easily searchable and indexed repository of ongoing design content.
2. The ability to post content ongoing concepts and resources on projects.
3. Commenting and reading reviews on content posted.

Now we consider more detailed responses underlying individual attitudes towards each of the three themes.

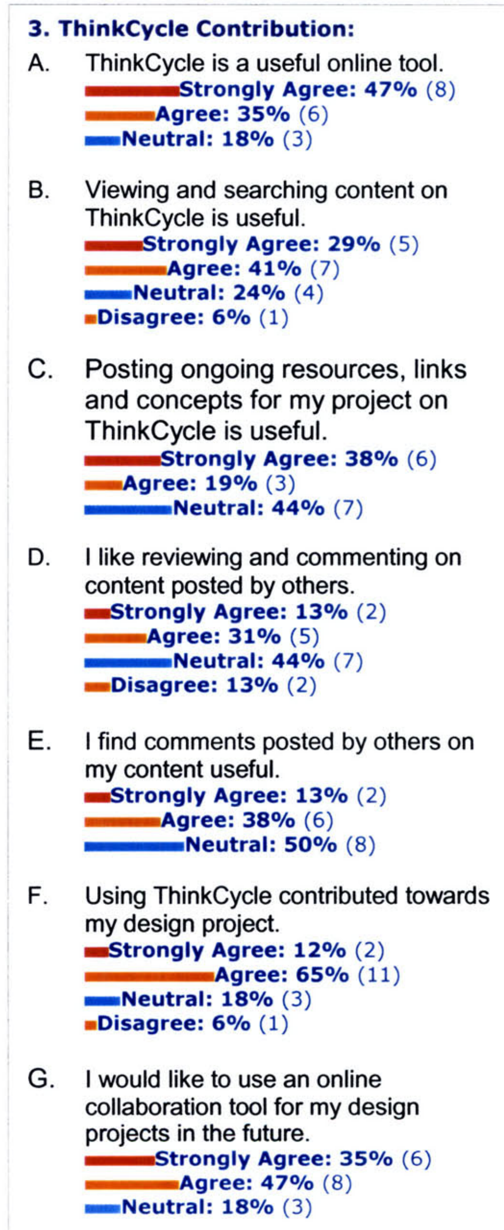


Figure 4.7: Perceived ThinkCycle contribution.

Useful Aspects of ThinkCycle: 4 Perceived Views
Respondents articulated several different perspectives of what aspects of ThinkCycle they found most useful. Their responses suggest four key functional views:

A. Shared Group Space: All respondents mentioned the notion of a "shared space" for exchanging files, documents and resources with teammates. In particular they liked the ability to easily upload large files and have the system automatically present their files on the web for easy access to everyone. Being able to notify teammates and coordinating reviews was helpful. Finally, some liked maintaining a private exchange within the team, while disclosing content publicly later.

"Sharing large files with specific members of the group ... and (email) notification when files were uploaded."

"The 'ThinkSpace' tool was very helpful for my project. It was nice to have an online space to put all my files and resources and have it accessible for others to view."

"It was pretty powerful as each project could have its own shared space where people could post their documents and design. It was comparable to (or better than) commercial applications that I use at work today for professional collaboration."

"It helped us coordinate certain aspects of the research we were doing, and allowed the team to review drafts of documents."

"Ability to make posting private to a few team members only and then open it to the broader community when the project is completed rather than open the entire time."

B. Evolving Project Repository: Another notion commonly expressed is that of an evolving file repository or documentation tool that allows people to capture the ongoing progress of a project. The system allowed version tracking of files and documents, enabling the team to recover the history of project without losing earlier work. This view is somewhat distinct from a "shared space" in that it suggests a temporal evolution and permanence of individual or group project memory.

"A webspace for documents… simple upload and auto document presentation. I do not have to manually code everything. It is like an iterative web building tool for documenting a project."

"A great site for archiving our on-line resources, references and project data files."

"I found that ThinkCycle was a great documentation tool for the project. It also was very helpful in showing people what I was working on without having to explain myself various times."

"(ThinkCycle) was an additional commitment to make a 'permanent' public presentation. As the final project had to be posted on the web, we had to think in terms of the archive."

"I really like the version tracking feature, which guarantees that I can always recover my latest file version even if someone edits the "master" copy."

C. Problem Solvers Area: Some users viewed the site in terms of finding "challenges" and solving problems (not only sharing or documenting), which provide learning in the design process.

"It's a problem solvers area. Engineers and other people who love to solve problems should check out the stuff on ThinkCycle; there's a lot of interesting stuff going on over there and especially the kind of problems which directly affect human beings. In solving such problems there's a lot of satisfaction involved."

"I found out about my initial cholera project on ThinkCycle. Also later on, it was useful to find out about the potential resources we could access."

"To browse all of the different real world issues posted."

"The fact that I can find out about the needs and the answers for those needs in the same webpage."

"It was also pretty cool to look at all the challenges on the site and see which ones I would be interested in working on"

D. Open Social Space: Respondents wanted to look at content posted by others, keep track of others progress, make people aware of their work and find relevant experts in certain areas. Many expressed a need to have others review their design projects (though it did not always occur). Social interaction in an openly accessible content space plays a critical role here.

"To look up links other team members posted."

"The ability to find out what other people in this space are working on."

"Giving the URL to interested parties so they can look at what our team is doing."

"Ability to locate people interested in precise issues or have expertise in certain design areas."

"… There's also the part about exposure - when I presented my project to the class and the online community in ThinkCycle."

"... Finally, companies contacted us to patent our idea, thanks to ThinkCycle!"

"It would have helped more if there were more people actively monitoring my project on the site and trying to find information for me."

These perceived views of the site suggest 4 distinct functions expected by the users, which clearly intersect during regular usage: ***Coordination*** (Shared Group Space), ***Documentation*** (Evolving Project Repository), ***Learning*** (Problem Solvers Area) and ***Social Interaction*** (Open Social Space). Such aspects play an important role for collaborative design in distributed settings.

How and when was ThinkCycle used in the design process?

Modes of Usage:

- *Gathering Resources* – users continued to informally search and gather online resources and add them to their project spaces throughout the design process.
- *Asynchronous Collaboration* – posting files and working documents for collaborative revision among teammates, particularly for large files not easily handled over email.
- *Distributed Collaboration* – exchanging ideas with teammates and domain experts in physically disparate locations, particularly when some were working on the field.
- *Soliciting Open Review* – posting concepts and ideas to gain iterative feedback from peers and a broader audience on ThinkCycle.
- *Course Awareness* – browsing the course site throughout the semester to check on class assignments, readings, schedules and guest speakers.
- *Lurking* – casually browsing project spaces to learn what people are working on.

Temporal Phases of Usage:

- *Pre-project Gathering* – collecting and organizing requirements, resources and background research in the early phase of the project.
- *Setting up Projects* – once a project was better defined, users setup "ThinkSpaces", added members and posted "Challenges" in their newly organized project space.
- *Posting Completed Work* – uploading a week/month's work after finishing a phase of the design or project work (e.g. CAD models, presentations or write-ups).
- *Design Review Updates* – most teams uploaded project-related files and updates right before the formal design reviews held in class.
- *Documenting* – though this ought to be an ongoing activity, many respondents mentioned that they seriously began documenting their projects towards the very end of the term, under pressure from the course instructors.

Situations where ThinkCycle was not considered useful in the design process?

Several respondents also mentioned reasons why they felt the online platform did not contribute as much to their design projects. Lets consider the key issues in their comments below:

"The team could function and work well without ThinkCycle but it was a useful tool for posting our final designs."

"For my project, I had the advantage of having a terrific domain expert available on campus. Therefore, our interactions were mostly personal (which was a lot quicker than if we had used the web). However, we did share some information that was posted on the web and that was really helpful. Especially background information was good to post on the site."

"(ThinkCycle) did not contribute much - there wasn't much external input on our design concept. What helped most was non-website related approaches like our expert panel."

"We only used it at the very end, so it wasn't part of our design process at all really."

"I think it helped in that others could post information. I only had a couple instances where that happened though. It would have helped more if there were more people actively monitoring my project on the site and trying to find information for me."

"On the project itself, it (ThinkCycle) was not so much of a resource as an additional commitment to make a 'permanent' public presentation."

Summarizing the key issues:

1. Physical proximity of teammates and domain experts for personal and face-to-face interaction minimized a perceived need for online interaction (though we find others who still found it valuable for asynchronous interaction and project archiving).
2. Lack of people actively monitoring projects online provided less incentive for users to post content.
3. Overhead of posting content was perceived as an additional commitment rather than a natural or integral part of the design process.

These responses are reiterated in the survey question that followed (below), however most mentioned "time" as the most compelling reason for their lack of active interaction.

What prevented users from posting content on ThinkCycle?

User responses point towards 6 main issues: (in order of frequency)

1. "Lack of Time" – response most often cited. (50%)
2. Being in regular face-to-face contact with team members and domain experts. (18%)
3. Posting content took too many steps; need a simpler interface like sending email. (12%)
4. Low site traffic or lack of users actively monitoring projects online. (12%)
5. "Critical amount of interesting content not quite there." – one respondent.
6. "Not part of my ritual." – one respondent.

A more reasoned explanation by one respondent suggests that the nature of online usage changed over the course of the design project:

"Depends in fits and starts of a project. For certain periods, I would hardly post, but during an intense project session, I would post a lot of content."

Several responses suggested the need for simpler interfaces, integrated into existing modes of communication:

"Time consuming and not following natural patterns of our behavior (email communication, etc.)"

"Just don't get around to doing it - Not always at a computer, when I have my brainwaves... logging in, loading up website and then typing seems like a task - it would be a lot easier if I could email my updates out to a centralized system that pasted them online on my ThinkSpace..."

"If I think about the barrier to entry to another method, email:
1. My email program is open at all times. For ThinkCycle.org, I have to open up that specific page.
2. I have to navigate through the site and find the appropriate subject to post my comment or cross link. Then I have to delete some text in the form and then submit. In email, I just write a subject, paste in the link/ write the comment and send it off. In summary I think it comes down to convenience and a saved 30 seconds per event."

Several respondents reason as to why they prefer not to engage in online discussions:

"Too much of a hassle to log onto forum everyday."

"I generally stay focused on the projects I have right in front of me. I may login and surf to see what other people are doing, but I'm more inclined to answer questions posed directly to me than to enter a general chat room discussion."

"I have never used a discussion forum before. I think discussions are suited to certain individuals and I'm not one of them. I don't think there is anything wrong with this implementation - it's just personal preference."

Another respondent blames the interface and navigation for his lack of comment postings:

"...Navigating the site. Lack of a visual map of where a project is at, and lack of a way to get to the parts I am likely to want to comment on quickly and intuitively."

What aspects of ThinkCycle were difficult to use?
Summarizing users responses, we find 4 key issues pertaining to usability, the majority of which have to do with site navigation and structure (rather than system robustness or functionality).

Site Navigation: 65% of the respondents encountered navigational difficulties while browsing the site, which can be categorized into two main types of *problematic navigational experiences*:

1. *Traversing a Maze:* Browsing a series of hierarchical menus and not being able to return to previous points in the hierarchy.

"(I) can't easily go back in tree hierarchy. From:
menu1 > menu2 > menu3 > menu4 > menu5,
it is usually difficult to (go) back to where one once was."

"At first it was very confusing to navigate around the site, especially to find my ThinkSpace... However, with time, using the site definitely becomes easier."

"You do need to click in and out of various areas, though there are many opportunities to take short cuts once you learn the navigation system... When I first navigated the site, I didn't find it frustrating to use - it was like a maze and I just kept clicking until I found something interesting."

2. *Disorientation:* Some users were unable to find content they posted or found themselves lost somewhere on the site; they did not seem to have a coherent spatial map of the site.

"Sometime it's difficult to actually know where you are as in what part of ThinkCycle you are in. It would be nice to know where you actually are and how you could go to other sections."

"Once in a while I had a hard time locating where I or another team member had posted something."

"Similar kinds of content could end up in vastly different places, leaving us to follow branches fruitlessly."

"There were no clear ways to see the stuff on a top level--there were too many clicks to get what you wanted and no good ways to have a broader overview.

Both of these experiences are not uncommon on many large and complex websites (though it is rarely studied and reported on such sites). Most users, like the respondents here, gradually learn the overall structure and navigational short cuts to effectively browse the sites over time. However, simple and intuitive navigation seems to play an important role not just for browsing information but also enabling sustained usage of a collaboration platform. Hence, one must consider appropriate solutions to address navigational issues that increase user participation.

Organizational Structure: 31% indicated that the organizational structure was non-intuitive, i.e. hierarchical layers, categorization, and terminology on the site. The "Filespace" referred to here is a web-based hierarchical file directory, an existing software module integrated into ThinkCycle.

"... the different categories of challenges, comments, resources, etc are a bit confusing. However, with time, using the site definitely becomes easier."

"... too many layers and definitions that are not intuitive. Ultimately there is a simple way to do this, not executed here (though nowhere else either)."

"It was oddly organized. I didn't know what ThinkSpaces were for a while."

"The Filespace in particular has a strongly non-intuitive organizational structure, and it's very difficult to correct posted mistakes. Even as a regular user, I often lose track of files."

Batch File Uploading: 12% found it cumbersome and time consuming having to upload multiple files one at a time, which "restricted the ease of use for file transfers and open access".

Information Clutter: 12% found the site "cluttered" with "too much information on one page".

New Features to Improve Interaction on ThinkCycle

A. Improved Navigational Interface:
It is clear that changing or enhancing the existing navigation and organizational aspects on ThinkCycle would ease most of the difficulties encountered by users. Though the site interface could be refined, a complete reorganization of the site and database structure would be infeasible. However, a pop-up site-map that tracks users on the site and provides context-dependent help and glossary of terms could make navigation on a complex site more intuitive.

B. Asynchronous Content Updates:
24% of the respondents suggested the need for asynchronous content updates to the online site, particularly via email. Batch file uploading can be addressed by client-side FTP-like tools or email-based mechanisms that parse attachments and upload them to the site.

"Having it connected to email so I can input entries via email without having to load website."

"If it were more integrated into my normal mail program somehow, if it had ways to create more content on-site."

"Off-line use capabilities, for users with infrequent, unreliable, or unbearably slow connections to the internet. In particular:
+ the ability to batch-upload ThinkCycle content developed off-line. In other words, I generate a pile of reference hyperlinks, images, topics, notes, comments, etc, and email or ftp them to ThinkCycle in a compressed packet the next time I'm connected to the Internet.
+ similarly, the ability to download a text or plain HTML overview of current topics on the site. The email update announcements of new topics, etc go partway towards this goal. It would be nice if I could request an email summary of all the activity in a particular topic over some specified period of time."

It also becomes clear that designers working on concept sketches find it cumbersome to scan and upload them regularly on the site. Hence, they suggested integrated scanning and sketching tools that can be used to scan/draw and upload several sketches to the site easily.

"Have a drawing tool (java) that connects to pen input for making sketches, and have an integrated scanning tool that immediately puts scans on the site."

"Being able to sketch online would be great – not having to operate in another environment before porting to web."

One solution is to develop an offline client application that asynchronously provides users with requested updates from the site and allows them to easily post text-based content (both without having to go online and browse the site). Later sketching and integrated scanning for batch uploads to the site can be added. Integrating such activities and parsing content via email is non-trivial. However, a Java-based client is being developed to test this approach.

Real-time Collaboration Tools:
It was expected that many participants would request real-time collaboration, however a significant number (35%) requested online chat integrated on the site. This suggests that participants view the design activity as a social process, with the need for spontaneous conversations with online peers supported by tools such as chat (in addition to email).

> *"When a team member is on-line I would like to chat with them. I use MSN with my team members in Montana and it helps to know when they are on-line, and give me instant access to them."*

Only three respondents suggested other real-time collaboration tools such as shared sketching, video-conferencing and shared file annotation. However, these were considered "interesting" options that may augment online interactions rather than a critical part of collaborative design.

> *"Ability to draw stuff on it - like a designers easel something like that would make it so more realistic esp. if communities from diverse places are communicating with each other."*

> *"Video conferencing would be an interesting collaboration feature. Perhaps having a video stream on a split window website allowing people to surf the site while talking about the project they are working on. This would be incredibly useful for showing someone your work while simultaneously getting feedback."*

> *"A way to work on the same file and track changes made by each user."*

Many off-the-shelf packages provide such functionality, however naturally integrating them into the design process and the user interface/database in an online site is far more challenging.

4.4 Key Themes and Recommendations

4.4.1 On Studio Courses for Sustainable Design

From responses to the studio design courses conducted over two consecutive years, it is clear that courses focusing on sustainable design through hands-on learning have a broad appeal among students, serve a valuable role in university curricula, and show concrete outcomes in terms of exposure, learning and working design projects. However, the success of the course requires not just well devised curricula and notable practitioners as guest speakers, but better preparation by instructors to develop well-posed design projects, more team/project mentoring, and greater effort to connect external organizations and domain experts with students throughout the design process. Opportunities for fieldwork before, during and after the course should be encouraged to make the design projects more relevant and meaningful to both students and stakeholders.

Though some students enjoyed an open-ended studio, others (typically undergrads) suggested added structure and deadlines to improve student involvement and project completion. Finally, most students agreed that the studio should be offered for credit to provide an additional incentive for them to seriously commit more time towards their design projects. However, course-grading schemes should be carefully devised to encourage collaboration, peer review and real-world assessment rather than emphasis on novel artifacts and competitive metrics.

Sustaining such studio courses in university settings requires: 1) strong commitment from university administration in recognizing the need and value for such courses to enhance real-world learning, 2) strong commitment from faculty in taking a lead on formally teaching novel studio courses or integrating socially-relevant design curricula into existing courses, 3) an important role for student instructors and domain experts mentoring teams during the design process, and 4) opening academic barriers to reach out to industry and field organizations to create mutually relevant partnerships towards real-world design projects.

4.4.2 *On Collaborative Design Platforms*

The survey indicates that participants find online collaboration tools useful and did indeed use ThinkCycle during the course. From usage patterns it seems clear that browsing and searching information was more prevalent than posting content. The web seems to be more useful as a medium for dissemination of information on sustainable design and resources, rather than primarily as a collaboration tool. Clearly participants do collaborate both face-to-face and using electronic modalities such as email and chat. However to encourage active online design collaboration, the affordances and usability of online tools must match their expectations with existing channels of communication.

Most respondents mentioned lack of time, being face-to-face, the overhead of posting content and lack of users monitoring their projects online as key reasons for not posting content frequently. Half the participants also found ThinkCycle somewhat complicated and time consuming to use, due to difficulties in navigation, structure and some interface issues related to file uploading. However, most managed to learn to use the system over time and adapt to the structure of the site.

The survey responses suggest four ways in which users viewed the online system: 1) *a shared group space*, 2) *an evolving project repository*, 3) *a problem solvers area* and 4) *an open social space*. These critical affordances (though often intersecting) must be supported in online collaborative design tool. In addition to an improved navigational interface, many users requested tools for *asynchronous content updates* (via email or ftp-like clients) and *real-time chat*. Overall responses suggest that users view design as a *social process* rather than simply one of archiving and exchanging data.

Navigation and interface issues can be gradually resolved, yet social/cultural factors seem to have a more critical influence. Among engineering students there is a lack of prior experience and predisposition towards the notion of online collaboration; much of their design work tends to be hands-on and face-to-face. Hence, such online tools are perceived as an additional commitment, rather than a natural part of the design process. There needs to be greater exposure to such tools including some training and examples of how it can be useful in the design process. In addition, online interaction and deliverables should be gradually introduced to students during the course, rather than expected from the start. Finally, having external organizations and domain experts (not co-located with the teams) actively reviewing the projects, serves as a more meaningful incentive to have teams place their evolving designs online and use such an approach.

4.4.3 Next Phase of Study: Open Issues for Inquiry

The online survey was unable to address many issues that were further explored using intensive interviews with several key participants from the course. The main themes of inquiry include:

A. *Nature of Design Process:* Understanding the evolution of design projects including key design criteria and decisions, social interactions, and artifacts created. How did the teams research, document and negotiate design constraints and concepts? How was peer-review solicited and incorporated in the design? What influenced the design process the most, and what were key motivations behind critical design decisions? How did the team use ThinkCycle in the design process?

B. *External Linkages:* In what manner did students interact with external organizations and domain experts throughout their design process? How did they seek out such linkages and maintain them through the course? How did these interactions influence their work and learning? What were incentives for external peers to get involved, and how did they benefit from the interaction?

C. *Intellectual Property and Public Disclosure:* We need to examine individual experiences in prior design projects in terms of disclosure and patents. To what extent did team members disclose their designs publicly (in class or website)? What factors prevented them from greater disclosure (competition, maturity of ideas, overhead involved, or market potential)? To what extent did the design projects benefit from external input? Does the team plan to field-test, patent, license or disclose their ideas in the public domain? Do team-members wish to participate in open source projects in the future? Under what conditions?

In the next chapter we will consider these issues, but focus particularly on social perceptions and approaches towards intellectual property rights in collaborative design projects.

5 ROLE OF INTELLECTUAL PROPERTY RIGHTS IN OPEN COLLABORATIVE DESIGN

Intellectual property rights (IPR) play an important role in making design innovations accessible to target communities and producers in developing countries. Property rights in scientific research and academic settings have always sparked intense debate about the public vs. commercial nature of research conducted and its impact. Interestingly there are two trends increasingly at play in such settings: a push towards greater commercialization or privatization of research through formal IPR mechanisms like patents and copyrights, while there is growing support for greater openness towards academic programs and research through Open Source initiatives. There is an opportunity now to consider the novel approaches that support multiple views of IPR to spur greater innovation in critical problem domains.

In this study, I examine the social perceptions of property rights and nature of IPR policies adopted among product innovations in university settings. We consider 7 case studies of product innovations from the *Design that Matters* Studio course offered in spring 2001 and 2002. Intensive interviews were conducted with 10 students from the studio course, while additional interviews with 3-4 university researchers were also conducted to validate some of the findings. The outcomes from these interviews inform the analysis of IPR for open collaborative design.

The preliminary analysis suggests that despite the ambiguity surrounding property rights among student innovators, they seem to have clear and strong rationale for dealing with IPR questions. There are diverse and reasoned notions surrounding patents, suggesting many important attributes that informants seek such as recognition, control, learning, preemptive protection and enabling commercial production of their work. However, there is surprisingly greater ambiguity and skepticism about Open Source policies, being regarded as noble or academic exercise rather than an operational IPR policy. Informants are not clearly convinced that Open Source policies can be adopted in hardware design, and there is a sense that the social reciprocity of cooperative design is not always emphasized in the process.

Several factors influence changes in IPR approaches adopted by innovators, including 1) recognition of innovations as being "under the radar", 2) deferred or territorial scope of patents, 3) institutional biases and stakes in the project and 4) the role of formal or informal social contracts. In examining the 7 projects in the study we find them aligned within a typology of four emerging IPR patterns based on level of public disclosure and formal/informal nature of IPR desired. We consider the key characteristics and rationale for adopting each of these patterns.

Finally based on this analysis, we close by summarizing the ten key attributes and incentives for IPR in university settings. I outline several approaches and policies that can be adopted to support both formal and informal IPR for critical design innovation.

5.1 Property Rights in the Context of Scientific Research in University Settings

The role of intellectual property rights in scientific research has always been controversial with many arguing for either a "pure" and public exchange of research vs. the necessity of commercialization and patent protection to spur innovation and entrepreneurship. The trend in the last 2 decades, towards increasing number of patent filings in academia, greater availability of capital investment for research commercialization, and newly established university licensing offices would point towards a greater privatization of scientific research. Many have argued that the implicit outcome of this trend threatens to undermine the effective role of academic and scientific institutions in the "public sphere".

However, some recent trends in the *Open Source* movement over the last 5-10 years also indicate a greater awareness of the potential benefits of public exchange among software components and standards (at least in the computer sciences). Novel educational initiatives such as *OpenCourseWare*[50] at MIT, boldly seek to apply such principles to public distribution of educational content as well. The *ThinkCycle* initiative at MIT towards open collaborative design in product innovation also emerged in this setting, having been influenced by similar thinking among its participants.

On the surface, both these trends would seem to be in opposition and often create much debate and controversy in academic settings. How does one reconcile the emergence of such diametric notions of intellectual property rights in university settings? Are there really two opposing camps to which individuals and institutions find themselves aligned closely i.e. *Public/Open/Pure vs. Private/Closed/Commercial* or is this distinction generally misleading in practice? How does the notion of property rights emerge in these settings and how is it negotiated to serve public or commercial interests? Is there a framework that accommodates diverse views towards public and private interests, while retaining the spirit of innovation and collaboration in scientific research?

My main interest here is to better understand the underlying motivations and policies to propose a framework for IPR, which focuses on fair exchange and timely impact of scientific innovations developed in universities, particularly in developing countries and critical problem domains.

5.1.1 Key Research Objectives

- Understanding *how Intellectual Property Rights (IPR) are perceived and redefined* in the process of open collaborative design and field-deployment of product innovations developed in university settings.
- Proposing a framework for IPR that provides appropriate policies, incentives and mechanisms to ensure *fair and timely access to scientific innovations* for individuals and institutions in *developing countries and critical problem domains.*

5.1.2 Study Approach

I. *Review of IPR in the Scientific Community:* Understanding key issues, social incentives and legal frameworks, based on existing literature and discussions with the Technology Licensing Office at MIT.

II. *Emerging IPR in DtM Projects:* Interviews with lead members of 7 design projects conducted using ThinkCycle in the MIT Design Studio in 2001 and 2002, several of which are being commercialized or deployed in the field, while others remain in the design stage.

III. *IPR in University Research:* Additional interviews were conducted with several researchers in university settings who deployed their socially motivated innovations on the field, such as household water treatment, wheelchair and medical incubation technologies.

5.1.3 Property Rights in the Scientific Community: A Sociological Perspective

In a recent essay on property rights in scientific research Robert Merges [1996], at University of California School of Law, argues that the current norms (both formal and informal) as practiced by researchers, suggest a form of *shared access common area* with limited membership, rather than a purely restricted space or a wide-open public sphere. Merges finds that the "science is not so much given freely to the public as shared under a largely implicit code of conduct among a more or less well-identified circle of similarly situated scientists". This revised understanding of the traditional notion of scientific openness provides a more pragmatic framework for policy directions that may better alleviate the "creeping privatization" that characterizes scientific research today.

Merges refers to critical observations made by sociologists studying the nature of the scientific community. Robert Merton [1973] describes the highly competitive nature of the scientific enterprise, regulated by a complex set of both formal and implicit norms. Four such norms assumed include: 1) *Universalism:* research judged independent of the personal characteristics of

[50] http://ocw.mit.edu

the scientist, 2) *Communism:* scientific findings made available to all, and not held proprietary, 3) *Disinterestedness:* scientists pursuing truth rather than self-interest are ideally indifferent to the success of their experiments, and finally 4) *Organized Skepticism:* the scientific community should rigorously test any research results before accepting them as true.
However, these norms are recognized as ideal forms of behavior rather than actual practices. Sociologists have found many practices that clearly deviate from such norms. Warren Hagstrom [1965] points to many "proprietary practices" emerging among scientists from a fear of misappropriation their ideas. Hence, the extent to which they can establish property rights over their work alleviates some of this anticipation, allowing them to collaborate, agree to a division of labor or share publicly. Hagstrom mentions an implicit mechanism of protection that scientists use is to publish research abstracts, which allows them to "stake a claim" on research in progress. In competitive research areas, scientists don't usually refuse to share information but simply do so selectively. Finally formal property rights using patents apparently provide a form of absolute exclusivity, which would be inconsistent with the informal norms in the community. However, in reality within this community potentially patentable or patented results are often shared, though on a more limited basis.

Some implicit operational principles can be summarized as follows:

1. If there are higher intellectual or commercial stakes in a research project or if it is more expensive/difficult to create, researchers are less likely to share results openly.
2. Property rights are most aggressively enforced with direct competitors, however creators are more willing to share results with people in unrelated fields.
3. Scientists use implicit mechanisms like publishing abstracts or institutional recognition (such as awards or press articles) to stake claim on their research.
4. Informal property rights are generally neither shared openly nor kept proprietary; in practice findings are shared selectively or delayed long after publication.
5. Formal property rights through patents, though exclusive in nature, are usually shared informally on a limited basis.

Paradoxically, Merges finds that despite the widespread use of patents this "informal ness" of property rights among the scientific community is maintained by "relinquishing (or at least not asserting) some of the scientist's formal rights". Hence there is a continued practice of "costless sharing" despite patents. Much of the debate in reality does not center on the exclusivity of research but on the "terms of access" i.e. whether the restrictions imposed are in keeping with the operational norms of shared knowledge as currently practiced.

Given the existing norms in the scientific community, the debates on property rights and widespread use of patents, what motivates researchers to obtain patents on their work? One can consider a number of different factors:

- Financial gains from licensing royalties in the distant future or incentive to commercialize the research through startup ventures or product opportunities.
- A form of public recognition gained by the formal legitimacy of a patent.
- Being able to "stake a claim" to a research in progress via early patents.
- Institutional pressure to demonstrate relevance of one's research via patents filed.
- Merges argues "the increasing (perceived) value of patents makes adherence to traditional community norms of open access implicitly more expensive". For example to overcome the potential threat of patents filed by others in one's own research area.
- Merges also cites a possible perspective from game theory, which would hold that individuals would abandon shared community norms in light of higher personal payoffs; here the "equilibrium strategy" would be to defect (from the norms to seek a patent).

5.1.4 Potential Framework for IPR in the Scientific Community

To develop a framework for dealing with IPR in the scientific community, we must examine several different potential policies and proposed mechanisms. We consider approaches that lie between absolute policies that suggest either fully proprietary protection and wide-open IPR in the public domain (including doing away with patents entirely). In light of current norms and trends, policies that leverage important elements of both and coexist with social norms and incentives, would seem most pragmatic and effective.

1. *Experimental-use doctrine:* Merges argues for exemptions from patent infringement liability for researchers engaged in "pure research"; this could be extended to individuals or organizations engaged in testing and modifying designs for field experiments. In most cases this doctrine may already be informally practiced. However its not clear if it is easily accessible to individuals and institutions outside of the scientific community.

2. *Multi-tiered IPR Transactions:* Currently IPR transactions are regulated either among scientists or with commercial entities. Merges points out that the informal transactions among scientists are conducted in the "shadow" of the formal transactions with commercial entities, hence unpatented IPR also comes with restrictions in many cases. He suggests that this 2-tiered configuration is only one of many possible. One possibility, in my mind is establishing a multi-tiered framework for transfer/exchange of property rights among different entities with differing terms such as: a) the scientific community in academic or public-funded sectors, b) commercial entities, c) nonprofit entities such as field organizations and medical institutions in developing countries, d) awareness and accessibility among the general public. This may be the way that most university technology licensing offices implicitly work anyhow. Clearly both formal and informal mechanisms should continue to play an important role in all such transactions. However, transactions among all these entities will continue to be conducted it the shadow of others, implicitly leading to terms or restrictions imposed which may not always be agreeable to all.

3. *Open Source:* Generally the open source approach is most effective as a *process* for co-development where expertise is distributed, rather than simply being a *policy for dissemination* of a finished product. Hence there may be compelling arguments for such cooperative development initiatives in specific problem domains, however applying the principle broadly to the output of all scientific research seems inappropriate. Yet it can be justified as a mechanism useful in specific areas such as standards, protocols, research tools, enabling technologies and such, where shared evolution of the design is crucial towards success of the research.

4. *Patent Pools:* In a review paper on patent pools, Merges [1999] writes "A patent pool is an arrangement among multiple patent holders to aggregate their patents. A typical pool makes all pooled patents available to each member of the pool. Pools also usually offer standard licensing terms to licensees who are not members of the pool. In addition, the typical patent pool allocates a portion of the licensing fees to each member according to a pre-set formula or procedure." Historically, to protect the public good, governments have created collective rights organizations: mandating compulsory licensing of patents at established fees, creating and managing public patent pools, directly purchasing key enabling technology patents and placing them into the public domain, and even creating mergers between firms[51]. Private institutions or industry-led consortia have also organized private patent pools including small contract-based patent pools, large industry-wide patent pools, and technology standard-setting patent pools. Since 1856 such patent pools have been created to spur industries such as sewing machines, aircrafts, radio, MPEG and DVD standards, and in biotechnology. Most recently such patent pools are being proposed to provide access to affordable AIDs drugs in developing countries [Love2002]. I believe this is an approach worth examining more closely with regard to scientific or product design innovations for tackling critical problem domains in developing countries.

[51] Articles on patent pools, Consumer Project on Technology. http://www.cptech.org/cm/patentpool.html

5. *Recognition through Public Awards:* Merges cites historic debates on patents for pure sciences in Europe, centered on the League of Nations in the 1920's and 30's. Though many proposals were made, one that was eventually adopted by the government of France was a decree creating a "Medal of Scientific Research" with prizes, which took the place of so called "discovery patents". This decree along with some legislated principles in socialist countries, were the only actual "legislative products of the scientific-discovery patent movement". This form of public recognition potentially provides many of the perceived benefits of patents such as legitimacy, authorship and financial compensation, without necessarily imposing formal terms for restrictive usage or infringement. As we will see in one of the case studies, a prominent award at MIT may have supported one of the design teams to refrain from seeking a patent on their work. A similar approach is used to recognize grassroots innovators in the Honey Bee initiative in rural India [Gupta2000].

This represents only a few of many possible approaches, any combination of which could be used in framing novel property rights policies for research institutions and innovations in critical problem domains. We will later examine which ones appear to better support IPR access for collaborative design innovations in developing countries, based on actual case studies.

5.1.5 Institutional Perspective: Technology Licensing Office at MIT

To better understand the motivations and decisions made by students, faculty and researchers regarding their innovations in the university setting, it is instructive to examine the nature of the IPR arrangements, policies and support available (or perceived as such). For this purpose I had an informal discussion with Anne Hammersla, the associate intellectual property counsel at the MIT Technology Licensing Office (TLO) in March 2002. Anne advises the MIT community about IP and licensing policies, working on consortia agreements and dealing with conflicts of interest. The discussion centered on the guidelines and support for student innovations at MIT; several key points include:

- *Inventions originating in coursework:* Typically inventions developed by students in courses are exempted from MIT ownership; however graduate students doing projects related to their funded research may need to turn their IPR over to MIT. In most cases MIT may choose not to exercise its rights on student work originating in courses.

- *Joint Inventorship:* Any contributors to an invention may jointly file for a patent at MIT. In the case of faculty, researchers and graduate students, the institution (MIT) usually has ownership over patent rights as the work is conducted under agreements signed as employees of MIT. However, work done by undergraduate students is usually exempted from MIT ownership (unless it is done under sponsored research). Hence, undergraduates may file for independent patents on their own or choose to assign their rights to the institute, which would file patents on their behalf, undertaking the financial costs and providing royalties from future revenues. In cases where an invention is jointly developed by a mix of graduate and undergraduate students, and/or external participants (outside the institute), the patent rights are distributed among several joint owners e.g. the graduate students/faculty would be collectively assigned as one joint owner, while the undergraduate student or external participants would be assigned as 2^{nd} joint owners. Each joint owner has the right to exercise their IPR independently i.e. commercialize, transfer IPR or handle revenues as needed; one joint owner (group) cannot block another, although individual members of a joint ownership must have mutual agreement.

- *Exclusive Licensing Rights:* Companies may be interested in gaining exclusive rights to manufacture a device (usually when the market is small and development costs are high). Here companies may wish to have both joint owners provide such rights to them or know how the other joint owners are making the IPR available to other companies that may compete with them in the future. One question is whether any company in the industrial or developing countries would choose to manufacture devices if it were not granted exclusive rights?

- *Patenting vs. Licensing:* IPR developed at the institution may be patented and/or licensed. It is not necessary to patent an innovation (though it seems to be the trend), before licensing it for commercial production (though some licensees may expect a patent for protection). Despite obtaining a patent, the joint owners of the patent may choose to establish varying licensing arrangements for making their IPR accessible to others. Hence, joint owners may decide to impose fees and restrictions for commercial production of a device, while providing a royalty-free arrangement for nonprofit use and so on. Thus inventors have great leverage in the licensing of IPR, even relinquishing some formal rights and claims if they choose to do so under certain circumstances.

Follow-up interviews with the TLO, based on specific cases at MIT (particularly from the DtM Design Studio) would yield greater clarification and assessment of the IPR issues involved.

5.2 Study of Intellectual Property Rights in Collaborative Design

With this background as a basic context, we can now consider how property rights are perceived and redefined in the process of design innovations in university settings, intended for field deployment. We have considered the formal institutional IPR mechanisms in place at MIT. We now closely examine 7 student design projects, and later several university-based research projects where property rights were defined or negotiated in different ways.

5.2.1 Research Questions for this Study

Key questions to examine closely include: (many others emerged as the study progressed)

1. What motivated team members to work on their chosen design projects?
2. What were their prior experiences and biases towards collaborative or open projects?
3. To what extent were the projects setup as open or closed by the innovators? Why?
4. To what extent were the projects perceived as open or closed by the others? What form of access was made available to people outside the primary design team?
5. What formal and informal mechanisms for exchanging or disseminating property rights were used?
6. How did external contributions or peer review change critical design decisions? What mechanisms or incentives facilitated such contributions?
7. Under what conditions did particular teams decide to patent, license or ignore formal IP mechanisms? What key factors influenced their decisions? How did their view change over the course of the project?
8. How did their IPR approach enable them to better leverage resources for desired outcomes?

5.2.2 Projects selected from the MIT Design Studio

To better understand approaches towards IPR in design projects, I examine several case studies where innovators made decisions to take their prototypes to the field, patent or license them, or setup companies to bring products to market. In the *Design that Matters studio course* taught at MIT in 2001[52] and 2002[53], there were several projects undertaken each year. For the purposes of this study, 7 projects were studied more closely i.e. ones which proceeded beyond the design stage, making the IPR issues more critical for the innovators. These projects demonstrate a range of attitudes exhibited by innovators. The analysis provides a framework for the nature of IPR patterns that emerged and how sociological notions of IPR were redefined in the process. In the analysis, I also take into account 3-4 interviews conducted with university researchers, whose projects were deployed on the field or patented and commercialized. The IPR issues emerging in these interviews (not documented here) provide additional evidence towards rationale for the attitudes adopted among students developing design projects in sustainable technology.

[52] http://www.media.mit.edu/~nitin/thinkcycle
[53] http://www.thinkcycle.org/dtm

Projects from Design that Matters Studio 2001

1. ***Cholera Treatment Devices:*** This project was initiated by an inter-disciplinary design team consisting of three MIT engineering students, working closely with local domain experts. 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. All the concept sketches, detailed design specifications, prototype CAD models and images were archived on ThinkCycle with annotated comments. 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[54] designed by the team. Critical feedback from two doctors at the Massachusetts General Hospital helped the team recognize real world constraints for practitioners and narrow their designs accordingly. In March of 2002, the team was contacted by representatives from healthcare company in Florida, to license their innovations for production. The team is working closely with the MIT Technology Licensing Office to obtain three patents on their innovations before pressing further.

   Status: Successfully prototyped; currently in process of patenting and licensing. All designs and rationale thoroughly documented on ThinkCycle with full public access.

2. ***Low-Cost Eyewear:*** This project also emerged from the DtM 2001 studio based on the interest of one of the instructors, Saul Griffith and speakers who discussed challenges in low cost eyewear. The innovator met with students at the Harvard Business School, who were also looking for suitable technologies and business models for delivering low cost prescriptive eyewear. Over the course of the year the original innovator developed a low cost eyeglass-manufacturing device and teamed up with two others in a precision engineering course to develop a hand-held prescription measurement device. For various reasons, few details from the project were posted on ThinkCycle; hence much of the designs remained proprietary. The team has now initiated a for-profit startup venture[55], based in Washington D.C. to commercialize the technology in the developing world.

   Status: Successfully prototyped and patented, and in the process of commercialization through a startup company. No design plans or rationale documented on ThinkCycle. However some designs were documented on separate private website.

3. ***Hand-Power Generator:*** The goal of the project was to design a device capable of generating up to 5W of power and storing it conveniently and at low weight and cost for later use. The power would be made available at an appropriate range of voltages to drive a generic array of electronics devices. With more than 3 billion single use batteries going to waste in the US alone each year, such a device could also be very useful environmentally. The design concept was based on the "bull-roarer", an indigenous instrument that utilizes the swinging of a weighted flat piece of wood at the end of a piece of string to generate low frequency sound. The swinging input mechanism is extremely efficient in terms of coupling human power to rotary motion. The prototyped developed used this mechanism for charging a set of rechargeable batteries or a super capacitor. All design models and electronic schematics were posted on ThinkCycle.

   Status: Successfully prototyped and patented, but not licensed or commercialized. All design files archived on ThinkCycle, while the visual design process[56] and design CAD models[57] were documented elsewhere online for public access.

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[54] http://www.mit.edu/~tprester/DtM/
[55] http://www.lowcosteyeglasses.net/
[56] http://web.media.mit.edu/~saul/thinkcycle/webtst/
[57] http://web.media.mit.edu/~saul/bettery/

Projects from Design that Matters Studio 2002

4. ***Passive Incubator for Premature Infants:*** The project aimed to design a passive incubator for premature infants. Every year, 4 million infants die within their first 28 days of life, with 3.9 million in the developing world. 25% of these deaths are due to the complications in prematurity, usually simple heat loss and dehydration. The lack of electricity in rural areas and frequent loss of power in urban regions renders a high-tech incubator worthless in these settings. In collaboration with Doctors Without Borders, the Brigham and Women's Hospital in Boston and faculty at MIT, the team developed a prototype for a low cost passive incubator, that will run independent of electricity. The team is currently in the process of testing the device followed by deployment in the field. The target users are rural clinics in Sri Lanka. On May 9, 2002, this team received the Lemelson international technology award at MIT[58].

   Status: Successfully prototyped and currently being field-tested. Design rationale and plans partially documented on ThinkCycle with private access.

5. ***Low-Cost Library using Portable Optical Reading Devices:*** In this project the goal was to develop an inexpensive microfilm storage device and reader to improve access to books in developing countries. Information is stored on microfilm rolls that would be housed in ordinary cassette tapes. The microfilm would contain 4mm x 3mm images that could then be magnified using simple optics and either viewed by a single user, or projected. An individual can use a binocular device held up to the eyes to view the information while a separate tool could be designed to display the image on a screen for multi-person viewing. The microfilm reader is battery powered, using a Light Emitting Diode (LED) as the light source for illumination. A single microfilm cassette can hold about 90,000 pages of text or graphics.

   Status: Partially prototyped. Design rationale documented (but not the design files).

6. ***Smart-Canes for the Visually Impaired:*** The visually impaired need intuitive and natural mobility aids, however most technology development in this area does not provide affordable solutions for all. This project was a culmination of research on prior art, fieldwork at the Canadian National Institute for the Blind, and rapid prototyping at the MIT Media Lab. An early prototype of a "smart" cane uses optical sensors and the blue dot cricket (as a signal processing circuit). The prototype is an adaptation of a standard cane, which functions as an electronic proximity detector, and relays distance information to the user by way of distance-dependant tactile (vibrational) feedback. Preliminary testing with a visually impaired subject showed encouraging results.

   Status: Successfully prototyped and prelim testing. Designs partly documented on ThinkCycle with private access only (design files only, no rationale).

7. ***Bio-sand Water Filters in Nicaragua:*** In the aftermath of the 1998 hurricane Mitch in Nicaragua, thousands of bio-sand filters were distributed throughout the country to provide safe drinking water to the population. Even though these filters have been very successful in other parts of the world (e.g. Nepal), their performance in Nicaragua has not been as impressive. The goal of this project was to investigate why the bio-sand filter has not been as successful in Nicaragua and to improve the design to overcome this limitation. Improvements in the design cover not only hardware, but also use (operation, maintenance) and education of the end-users.

   Status: Successfully prototyped and tested. The project requirements and design resources were documented on ThinkCycle, with public access.

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[58] http://www.mit.edu/~ideas/winners.html

5.2.3 *Methodology and Interview Questions*

Of the dozen or so projects from the MIT studio courses, the 7 projects selected here for the study have reached a sufficient level of progress or closure, that made the notion of IPR issues relevant to the participants. Intensive interviews were conducted with 10 lead informants who participated in these projects. Each interview lasted approximately 90 minutes, and was tape-recorded. Every interview was subsequently summarized and all conversations regarding IPR issues were painstakingly transcribed, to enable an ethnographic analysis of the informant's perceptions of intellectual property rights.

The following questions were posed to informants in the study. The interviews were conducted in an unstructured manner, and these questions primarily served as a means to engage the informants in a conversation, hence many questions were improvised based on prior responses.

Q1. Why did you join this studio? What did you expect to gain?
Q2. Why did you decide to work on this design project?
Q3. How was the team formed and whom did you consult in the process?
Q4. Describe to me how the problem constraints and design concepts evolved? Draw a timeline and show me the significant decisions your team made? Show me working sketches?
Q5. How did your team work together and communicate during the process? How did you resolve and negotiate key decisions?
Q6. How did other organizations and domain experts help in the design process? What do you think motivated them to get involved? What was their key contribution?
Q7. When did you use ThinkCycle in the process? Why did you find it helpful or not? What online tools would have supported your design process better?
Q8. In your previous projects, did you work in teams and what were some of the best outcomes? Did your prior projects get published or patented?
Q9. Did you feel comfortable discussing your project with others outside class? How did you solicit external review of the project? What prevented you from disclosing it more publicly?
Q10. Do you plan to continue working on this project? Will you field-test, license or patent it? Why or why not? If a company approached you about it, what would you do?
Q11. How do you think the project would have the most impact – through full public disclosure (open source) or proprietary licensing? Which do you think makes most sense in your project and why? What do you think about "open source" having gone through this project?
Q12. What are your long-term career plans? Where do you see yourself in 5 years? Do you see yourself playing a role in addressing social or environmental problems? How do you feel you can have the most impact?

In this analysis we will primarily focus on the IPR issues emerging from these interviews, while aspects of cooperative design and learning will be examined in more detail in other sections of the thesis (however they inform the IPR aspects discussed here).

5.3 Perceptions of Intellectual Property Rights in Collaborative Design

In this preliminary analysis we first consider some of the meanings, attitudes and perceptions that shape the informants views of intellectual property rights, and their subsequent approach towards their own design innovations. We will also seek to understand if and how these notions of IPR were redefined during the course of the studio design projects. Hence, I will draw upon and categorize spoken dialogues from transcribed conversations with informants.

General Perceptions: Patents vs. Open Source

Presence of Reasoned IPR Rationale despite Confusion and Uncertainty
The over-arching observation that one can make from interviews suggests a great deal of confusion and uncertainty about formal IPR such as patents, Open Source, licensing etc and particularly in the differences in tradeoffs and outcomes of these approaches. Most of the

informants do not have a clear or informed view of these issues. At first glance much of their thinking around IPR issues may seem simplistic or dichotomous, however when pressed with decisive scenarios and additional information, they provide surprisingly well-reasoned rationale for taking specific IPR approaches. Despite some ambiguity about the approaches, informants tend to argue strongly for (and against) patenting, copyrighting, licensing or Open Source. Some of the rationale begins to break down at the boundary conditions around Formal IPR and Public Good. At this junction there is much debate and evolving notions about appropriate approaches.

When pressed about formal IP approaches, informants attribute a diverse set of concrete notions to patents where as their notions around Open Source tend to be less articulate and more ambiguous. This suggests a greater exposure and perceived legitimacy attributed to patenting (both positive and negative attitudes) whereas Open Source is often treated like an experiment, fad or academic exercise. Overall patenting is considered a more useful and operational mechanism (despite being inappropriate in many cases), while the notion of Open Source is considered premature, "tricky" or unrealistic in real-world situations for a variety of reasons.

5.3.1 Diverse and Reasoned Notions about Patents

Patent as Recognition and Privilege: The most often cited attribute of patenting tends to be the level of social recognition and privilege associated with it. Almost all informants view receiving a patent as a positive and legitimate form of property right, akin to an "award". This stature associated with patents is key motivation for engineers (not necessarily researchers in the basic sciences), particularly ones who have not filed for patents in the past. It is often considered helpful in resumes and to get one's "foot in the door" when applying for jobs or talking to organizations. This suggests that any proposed alternatives to patents must provide a similar form of legitimate recognition as an important incentive for adoption.

> *"I'm not sure I can give that intelligent of an answer, but ... I think it would be cool to patent it because, this is really stupid, I've always wanted a patent, its cool to get a patent in college."*

> *"... well I didn't know anything about patents, even the possibility of having my name on a patent was just exciting. I never thought... well how many undergraduates from MIT would ever have a patent filed, even an application as an undergraduate. I would say its very few, very small percentage. So that was like a privilege."*

> *"... well it's kinda like a sense of accomplishment I guess for yourself. Umm... you know it's a pretty big deal to do something like that."*

> *"I don't think it (monetary benefit) was a large part, it was probably more that we can have "recognition" – that was probably more of a motivation."*

Patent as Real-World Learning: Some informants viewed familiarity with the patent-process as an important facet of learning about product development in the real world (presumably outside university settings). Some feel it is a "natural part of designing products" and hence the exposure is helpful.

> *"And so it was another means of... And from an individual perspective it's also a chance to become familiar with something that's a natural part of designing products within the commercial setting. So the process of learning about patents and licensing is another experience."*
>
> *"Plus, in terms of the education, I think it's important that people at least have an exposure to the processes that surround design, and designing products and designing ideas. For people working in an ideal environment like academia, that's another aspect of training. You have to get exposure to that at some point."*

One might argue that various aspects of patenting such as prior art search and documentation are a part of academic rigor (and could be reinforced in coursework and publications), however these aspects are clearly motivated by patent filing. The nature of conflicts and negotiations arising in the process of patenting and licensing can be considered a unique form of learning, not usually available in academic settings but is it the role of an academic enterprise?

Patent as Publication: In many cases a patent is referred to in terms of publications not unlike a journal article, given the nature of rigorous documentation and detailed drawings required. The fact that it is evaluated by "experts" and made accessible in a public database gives it the role of a legitimate publication. However, it is unclear as to whether informants consider the intellectual property *in the public domain* when it is patented.

> *"Another part of it was that it's also a form of publication, so you can have a more rigorous documentation of your idea in the public domain."*

An example of a patent perceived as public domain knowledge:

> *"Q: What happens after that one year to the public-ness of that project? If you patent it does it still remain in the public domain or not?*
>
> *No if you patent it then... by definition patenting is putting it into the public domain, but then people have to license it from you. So you know, everyone can still access the ideas and they can make that thing for their own personal use, but they can't profit from that thing."*

An example of why patent was not considered in the public domain:

> *"(I did not feel strongly about patenting) because first of all I felt slightly conflicted because I did want this to be in the public domain such that people could, you know if they wanted to use it."*

Patent as Preemptive Protection: There is concern that one needs to overcome a potential threat posed by others patenting the designs to avoid infringement. Hence a fear of infringement claims may lead to a perceived need for preemptive patent protection. Patenting is recognized as a protective mechanism providing legal cover for one's intellectual property. Alternative mechanisms proposed should ensure a form of legitimate protective cover.

> *"So that (Open Source) actually can be pretty dangerous, because then anyone can just kinda take your idea, patent it and then they can do whatever they want with your invention. And then if you develop your idea and its socially responsible – its also problematic in that of you try to patent it and you can infringe on their patent."*

> *"It seems like patents are a good way to kind of inspire people to work on something ... so like if there were no such thing as a patent, then anyone could just take anyone else's idea but its just kind of the way people work, you know.... I think that having a system like that in place probably has fueled some innovation over the years."*

Patent as Control: The most overwhelming rationale for patenting is attributed to having some level of "control" over how the intellectual property is utilized by others. This notion of control takes the form of 1) *Appropriate Usage:* ensuring the design solves the intended problem and target users or the idea does not get "exploited" i.e. used for the wrong purpose, 2) *Manufacturing Quality:* ensuing the device is manufactured in accordance with the design constraints and safety standards, 3) *Leverage to Negotiate or Intervene:* (perceived) ability to intervene in the production of the design when needed or negotiate how it will be used, 4) *Commercialization:* ability to commercialize the technology i.e. "raise that money and to get people to bank on your technology and assist you in the project".

> *"Umm, our motivation for pursuing a patent was a combination of having some element of control of where the idea would go. We worked on project with very idealistic goals in wanting to see the original (health) application as being possible with the new device. So that was a concern, so by patent you have some say over what happens to that."*

"I just, I would just want proprietary licensing to be able to make sure like our idea doesn't get exploited or like people don't make it wrong. Or if we have suggestions for it and if we don't like what some other company does to it, then we have some control over that. Umm, I guess I don't know ... it would save lives of premature infants. But I'd be sacred like, it's such a big thing... I don't know I'm just scared something would go wrong and it would kill a baby and we'd get into trouble."

"So, umm... then I was reading up on the fact that unless you actually have a patent on an idea its hard to control whether the idea is used appropriately by socially responsible people. So I decide to make it Private so I could control that.

Q: Control what exactly?

How... control that the people that would develop the idea would actually keep in mind the visually impaired people and their needs and not just develop a copy-cat product."

"... but the other way to look at it (patents) is that you're really covering bases in that you can control the idea, and you're getting credit for it. For example, if an idea isn't patent by the inventor then if the idea is taken by some company and used for some completely offline use you never thought of, then you have no course of intervention. No say in it. But if you had intellectual property protection covered on those designs then it gives you flexibility on how you'd like to see that happen."

"I think that if you patent it, you could... its your patent but it doesn't mean that you... restrict the use of it. So maybe you can patent it and give reuse for people who want to use it. Because in some last resort where you think maybe some people shouldn't use it or shouldn't take... say you leave your design open and everybody can use it and you see that some people are using it incorrectly, to what you think is incorrectly. Maybe if you have the patent then you have some leverage to negotiate with that."

"In some cases the patents add value, it gives you a huge degree of control over the project and its implementation. And particularly on those projects with a... you know pragmatically it requires money to implement it realistically. In those cases where you require a significant amount (of funding), you require a lot more control over your intellectual property to raise that money and to get people to bank on your technology and assist you in the project."

One must recognize the role of "control" as a critical aspect for patenting in the mind of innovators, not simply as a means for monetary reward but as one to ensure the appropriate usage and manufacturability of the device. However, it can be argued that it is not the patent itself but the nature of licensing that enables one to negotiate such terms.

Patent as Commercial Enabler: There is a notion that patenting provides a commercial incentive to bring the innovation to market, by allowing companies exclusive rights for manufacturing the technology and recoup production costs. The idea of formalizing one's intellectual property (via patents) ensured that there would be greater commercial interest. However it is not clear whether exclusivity is necessary or that even patenting is necessary for licensing an innovation to different manufacturers. Many competing products are indeed produced in the marketplace and differentiated by packaging, quality, target usage, cost and other attributes. There is some contention that exclusive rights may also be required in developing countries, however other informants suggested that had not prevented manufacturers in the past from seeking to produce similar products.

"The thing is no one is going to manufacture a device unless they can have some advantage in the market. And the only way to have advantage in the market is to have exclusive access to an idea. So the patent is almost an enabler for commercial production."

"We definitely thought it as being the right thing to do, because otherwise we didn't see anything happening with the project. We thought of it as way of guaranteeing that something happened with our design.

...

It just sounded like it was exciting because somebody was interested in continuing with the project and definitely the idea of it being made into a product was, for us, the best result."

Patent as Non-monetary: Most informants indicated that monetary concerns were not a driving motivation for obtaining a patent; they recognized that they would receive minimal royalties, if any. However others also indicated that the technology was usually in an area, which was not their main "profession". Most had not intended to pursue it seriously in the future, and hence were not relying on potential patent revenues for their livelihood.

> *"The whole aspect of royalties and license fees – its almost peripheral. It's such a simple device that's made easily, that we're not talking about huge dollars here."*

> *"Oh, it wasn't the monetary. We did a calculation, just for fun and even if they sold millions of these, we would get so little, it's not an issue."*

> *"I'm just not one to be about all that concerned about money, and two I don't think that this is like my main occupation or anything. I'm sure I'll be able to get a job and I'll have a good amount of money to live on. But I think it'd be kinda nice to get recognition for it..."*

Patent as Unethical: Some informants remarked about the negative connotations associated with patents with respect to monetary rewards. This connotation did not prevent them from patenting, but it did make them somewhat hesitant in the context of the social motivations behind the studio course. One respondent described the process of patenting as "swimming with the sharks" i.e. influenced strongly by commercial interests, which had made her hesitant to patent her work in the studio course.

> *"With patenting it's very easy to see it as just a way of earning income, so it's perceived as being money making ..."*

> *"ok, let me say it this way, when I think of "patent" I think of "profit" and when I think of this class I think of completely the opposite."*

> *"I'm very reluctant about the 2 patents I'm going to get, in terms of the process just because we are swimming with the sharks."*

Patents as Mystifying: Most young innovators in university settings are unfamiliar with the patent process and its implications. Once initiated, it can be an overwhelming process. Despite having gone through the process, many informants were still unclear and confused about many aspects of it. However having a trusted intermediary taking care of the process apparently alleviates such concerns and provides a lower threshold to enter the "patent game", particularly as the filing costs are undertaken by the intermediary and perceived risks are low.

> *"And then it was more involving because I was getting mailing like crazy. Every 2 days I would get 3 really thick files with information, with forms that I had to sign and etc, etc, etc... from the Technology Licensing Office here. And lot of emails where you had to cc many many people every time... and to be honest I still don't understand fully how this process works. I know... I mean they explained to me the general steps but umm... I'm not sure what is best to do or what we are waiting for now. So it's a little confusing. But they take care of everything, if you do it through MIT there's nothing you have to do except for signing forms."*

Conversely, a similar level of mystique may be associated with Open Source, however the process of placing one's innovation in the Open Source mechanism is not easily facilitated by trusted intermediaries. An interesting question to consider is whether the Technology Licensing Office or another intermediary (perhaps a nonprofit legal entity) provided innovators both options and facilitated either one on their behalf, would this change the incentives to patent by default?

5.3.2 Simplified and Cautious Notions about Open Source

In conversing with informants, in general there is less articulation about their perceptions of Open Source and a lack of the systematic rationale seen in discussions about patents. Most informants view it as a "noble" idea or academic approach but few regard it as a feasible operational concept for taking serious innovations out to market. Some of this perception may be attributed to a lack of prior exposure and working examples of Open Source innovations in the context of hardware. However, it is also clear that unless some of the attributes and outcomes associated with patenting such as recognition, control, publication and protection are addressed, few innovators would consider alternatives to patents if they wish to formalize IPR. Finally Open Source requires a notion of reciprocity such as cooperative development, the lack of which makes this approach less appealing.

Open Source as Noble: There is a negative perception associated with Open Source as being entirely altruistic or "noble", which would not ensure attributes such as recognition, control etc. This perception makes it seem less likely as a feasible operational approach.

> ***"It seems really noble. It goes along with the spirit of helping people, being good. I could see in some ways I wouldn't be happy with it. I'm not sure, like I really like getting recognition for things I do. "***

Open Source as Fad: A few informants exhibited skepticism about the idea of Open Source, particularly as it was regularly hyped in the media – so it seemed more like a fad. Clearly much of the extraneous publicity around Open Source changes its perception as a serious academic or commercial mechanism in their minds; this connotation of a fad might distance some from openly embracing the concept for their own intellectual property.

> ***"To be honest when I started the class it sounded kinda hoacky. Umm… just because Open Source was like the new… whatever, it was just the, everybody was talking about Open Source everything and I think it was getting, I mean its kind of like Sustainability is now. Everybody is talking about sustainable everything, sustainable breakfast cereal. Umm, I mean there is Open Source food (referring to the OpenCola beverage)."***

This pattern may parallel that seen in the software community when premature notions of "Free Software" (pioneered by Richard Stallman) first emerged; it wasn't until it was operationalized under a commercially viable concept of "Open Source" (by a group of mainstream software developers including Eric Raymond) which was adopted by some companies did the concept receive legitimacy in the public eye. Hence without sufficient examples and legitimacy, the notion of Open Source in hardware seems to be at this stage of perception.

Open Source in Software vs. Hardware: Some informants suggested that the hardware innovations require capital investment for manufacturing and distribution, which makes it difficult to adopt an Open Source approach here unlike software. However it can be argued that similar investment is often necessary in the software industry, and many protective mechanisms like copyrights have been used in the past. As we will consider later, the hardware/software distinction may be less important than that of the scale of production/distribution costs involved.

> ***"I think that there are good applications for it, I think that hardware is very different from software, umm… like fundamentally different from software. So, I … I don't know, you know I'm still on the fence regarding Open Source as a means for developing hardware."***

Open Source as Cooperative Process vs. Public Contribution: There is a clear tension between the notion of Open Source as a cooperative endeavor with multiple contributors vs. simply one of freely disseminating intellectual property. This lack of perceived reciprocity pushed at least one informant to go "Closed Source" when others did not seem to be contributing to his project online. But it was probably not the main reason, as another informant chose to keep his work open, despite lack of peer contributions.

> *"Umm… well Open Source is actually tricky, because Open Source can mean so many things. In one sense it can mean you share with people that are contributing to your project, for example if companies were going to do joint ventures. And to other people Open Source means it's completely open to the entire public."*

"I would say that I would have wanted to contribute collaboratively with people but it really didn't end up working out so I decided to keep it private. If lots of people in the community or elsewhere decided to contribute I probably would have kept it Open Source. Because once again, I was more interested in stimulating interest."

Open Source as an Academic Exercise: Informants in the context of the studio course, naturally treated their projects as pedagogical rather than real-world ventures. The institutional setting and lack of external stakeholders reinforced that mindset. Hence, the IPR approach in the early stages also reflected this academic nature, i.e. treating it as Open Source by default. However as the projects seemed more commercially viable ("a real solution") some informants did not continue to maintain an Open Source mindset, seeking patents instead.

"...it (the project) was Open Source in that, in doing the project I don't think any of us had really consider that this would become a Device. We were all pretty skeptical in the beginning in the potential of the course to really solve the problem. My interest was... the reason I liked the course was that it was exposing students to the problems. So I don't think any of us seriously considered that this thing would ever get built. Umm... so it did feel like very much an academic exercise. So publishing our designs, that was a continuation, at least in my opinion, of an academic exercise that some other students could continue and kind of chip away at the problem. Umm... just because it had a lot of elements for an academic exercise. Umm... but I never... certainly at the beginning of the class we didn't consider this as being kind of a route to a real solution and even now I'm not sure what else needs to happen to make it a real solution."

In summary, it seems that Open Source is still generally associated with academic experiments rather serious commercialization. To promote adoption of Open Source as a serious mechanism for product development, there needs to be a few good examples of projects having taken this route to market.

Does the discussion of Open Source vs. patenting in an academic setting introduce formal notions of IPR into the design process? This would prove to be an ironic and unintended outcome of pushing the Open Source approach in studio design courses. One informant argues that there is a danger that introducing such notions places a burden on students to grapple with difficult IPR issues and may induce them to be more protective of their work.

"The only problem with Open Source is that it introduces the student with this idea that they could make money from it or somebody else could make money from it, or that there's a risk that the design could be used or taken away from them."

"So, I think if I was to do the project again I like the idea that... I like the fact that in the beginning we weren't even told about patenting or Open Source or any of that stuff. But it was just "work on the design". I think that 90% of the time it's a non-issue, its not even going to come up, patenting. Just because it is very difficult to come up with a truly innovative design. And, so I think that putting this heavy load in the beginning on, you know, intellectual property and all this stuff could be misleading to students. Umm... because it makes them think that they are automatically going to arrive at some sort of intellectual property.

...

So it just makes them suspicious, less interested in communication and in the early stages of the product when its crucial that they brainstorm and share ideas and ask questions, not feeling constrained in any way. And I think that the whole Open Source vs. Patenting debate becomes an impediment to a good design."

Though a pattern of protective behavior was clearly not exhibited by all informants, it still seems to be a valid issue to consider while introducing IPR aspects in design courses.

5.3.3 Factors Influencing Changes in the IPR Approach: Biases and Conflicts

The interviews point to at least four areas of conflicting factors, affordances or biases that emerge in the process of development. These influence the manner in which IPR is perceived and the nature of approaches adopted. These are summarized here:

- Perceived Scale or Impact of Innovation
- Scope of IPR in terms of Deferred or Territorial Enforcement
- Institutional Bias and Stakes in the Project
- Formal and Informal Social Contracts that Moderate IP

A. Notions of Scale: Being "Under the Radar" or "Sub-Threshold"

Informants often suggested the "scale" of development or impact of the innovation influenced their approach towards the IPR. For example, they would not consider formal IPR like patenting or licensing for small-scale projects that were directed to a specific community, while such notions would play a role for larger projects, particularly when interfacing with government or commercial entities.

> *"You know when you're working with Development Issues, when you're working with a rural village that hasn't heard of a TV, I don't think all these licensing things work. Honestly, I mean they wouldn't be very effective. Now on a bigger scale when you're talking about governmental hospitals, yes it would."*

> *"I don't think you should locally optimize things, like I don't feel like that kind of market would have been worth like hundreds of millions of dollars, might have been worth a few million dollars and unless you think its something that is really, really big and is really going to change the world, umm… then I don't think its really important to do patent protection on those kind of things."*

A notion of scale was also invoked with respect to the quality of outcomes of the innovation. Commercializing and engineering the innovation on such a scale required a "non-trivial expense" which changed their IPR approach.

> *"Q: So what changed (for you to switch from Open Source to patenting)? Did you find that…*
>
> *I guess realizing that we were making better than first quality lenses. And then realizing the expenses required to get that particular device built on the scale required to implement and make a real difference. And that engineering is certainly a non-trivial expense."*

Finally, informants often described scale by referring to innovations being "under the radar" of commercial interest. These "sub-threshold" projects were characterized as ones that would not be profitable if commercialized for the target users or have "self-supporting markets". Such innovations were considered best to be made available for nonprofit manufacture or distribution under Open Source licensing. Interestingly, one informant here points out that it is not always possible to know whether a project is "sub-threshold" or not; indeed many innovations when further developed emerge above the "radar" of commercialization (in the minds of the innovators as the technology seems promising or when solicited by companies).

> *"Idealistically I think it has a lot of potential, in terms of working on problems of this nature where they don't have a lot of… they're sort of under the radar than things of more commercial interest."*

> *"So for any large scale project you need to raise the money to do that, and IP is critical in most cases. Now there are a whole bunch of sub-threshold projects which will never be profitable which need to be done in the way that they should be open domain. Things like that are the baby humidifier, no patent would ever justify its expense in that domain. Umm… and you know I think there's a very large number of projects that are like that, things that should exist but are not self supporting markets.*
>
> *…*
>
> *You don't always know in advance what the sub-threshold versus the non-sub-threshold project is. In some respects I thought that (my design innovation) may have been sub-threshold."*

> *"Q: So tell me when you put something public and when you didn't - when you made a decision to be a bit more low profile about it.*
>
> *Ummm… upon realizing the potential of some of the (manufacturing) processes, and (recognizing) the fact that the way to fund the whole project might be to sell that IP and that IP – realizing that it had a*

high value potentially, meant that it was unwise, if we are going to purse this to negate our access to…. [garble] publishing or not."

B. Scope of IPR influences Formal Assertion

The informants consistently suggested that the scope of IPR in terms of its temporal and territorial validity influenced their decision to seek formal IPR, particularly with respect to maintaining access in developing countries. Lets consider the rationale for both aspects here.

Deferred Assertion of Patents: All informants who considered filing for patents, pointed out that the one-year period after publicly disclosing their ideas, enabled them to defer the decision to patent (only valid in the US) and in many cases leave the designs publicly accessible during that period (and after). In 2 cases though, informants chose to keep the designs private for reasons we will consider later. This one-year rule seems to be a critical juncture for decisions regarding the "sub-threshold" question, the patentability of the idea and a rush to get the designs to a stage where patentability can be resolved. Without the one-year buffer, as practiced in European patent law, it is likely that innovators would either file for patents immediately, keep designs private or make a decision to leave designs publicly accessible from the onset (in effect relinquishing their right to patent).

> *"I think the nice solution is this one year – you can work on a project for a year and then you haven't negated your capacity to … I think that one year in nearly all cases is enough time to determine sort of the sub-threshold question, if you like. And then you don't negate your opportunity in applying for a patent, which in some projects is probably more optimal in terms of seeing their realization, and in others that would be its detriment. So you get that one-year to analyze it… think about it."*

> *"We were fortunate in that if they (the company) had contacted us two months later it would have been a mute issues, because we had only a year after public disclosure to actually patent our designs or to apply for a patent."*

> *"I wanted to work on getting a patent because you have a year from the time you make the patent public, I mean the idea public, so that's actually coming up."*

Territorial Scope of Patents: A key factor influencing informants to patent their innovations, while seeking to maintain access in developing countries was the notion that the patent would only be enforced in the US, i.e. individuals and companies in developing countries could always manufacture it without any legal recourse. This territorial scope enabled innovators to retain the intended spirit and impact of the innovation, while allowing commercial production in the US. However, there was also a recognition that the products manufactured in developing countries could not be exported to the US, and that in some cases companies in the developing countries may seek exclusive manufacturing rights as well (though another informant later pointed out that this had not stopped companies in the past).

> *"We made it very clear in our discussions with TLO that our motivation was to have this available in developing countries and through our discussions with them and realizing that internationally the idea's out there anyway. So the motivation to where it was freely available as an idea internationally. And so within the US it may be protected but internationally people can do whatever."*
> …
> *"I'm not sure where they negotiations are. But it's really a question of US market at this point. Cause anyone internationally can make it … they couldn't import them to the US, so that's a factor as well."*

> *"And I know that the patent process is, in a worldwide, in a global sense quite complicated and simple in the sense that its possible to protect locally but not globally, such that you can, you know, make money off a product made in this country and still provide people with access in developing countries."*

> *"Originally we were excited because, because we had disclosed the technology prior to applying for a patent, it meant that it was unpatentable anywhere else in the world. So our patent will only apply in the United States, and this design cannot be patented outside of the United States. And we thought that it*

> *was the perfect solution; because that meant that an American company could develop this technology but a company, say in West Africa or India, could pickup the design without having to pay any royalties."*

> *"so we kept on having discussions and what came out was that, in the US it would actually be commercially applicable, so if someone were to use this patent they had to pay royalties to MIT and that would increase the cost of the product etc. But if the technology or the idea was used in an international setting, lets say in India or Argentina then there was no issue with MIT. I think that pretty much settled all the concerns we had, because we know that it could be used in developing countries and there would not be any financial issues to deter these countries to use it."*

Hence the temporal and territorial scope of patents in the US provides a useful solution to the question of public access in developing countries.

C. Institutional Bias and Stakes in the Project

In the interviews it was clear that institutional factors including stakes and biases play an important role in the notions of IPR emerging among innovators. Three such factors include: 1) Academic setting influences ongoing stake in the design and the ethics of patenting, 2) Culture of Innovation at MIT and Presence of TLO influences assertion of patents, 3) Collaboration with external entities or having a nonprofit entity administering the IPR.

Role of Academic Setting: Clearly most informants were primarily influenced by the social motivation in the course and the academic setting with respect to the IPR for their innovation. In addition, the change in level of venture funding at the time also influenced their approach. However later we consider examples where, despite the social and academic context, informants considered formal IPR approaches appropriate for a number of reasons.

> *"Q: What would you have done with this maybe before you started this course, and maybe something change or did you feel differently?*
>
> *Yeah, well I think probably if I'd been in kinda situation like that 2 or 3 years ago, I think probably I'd be thinking more of like getting a patent and start a company, get my IPO and sell out the stock you know and retire at 30 or whatever but...*
>
> *Q: Because the climate was different then...*
>
> *Yeah, even if it wouldn't be like a dot-com type thing but you know that's what you'd be thinking... but I mean, I definitely after taking the class umm... I think I'd think a little bit more about you know the effect it can have on the entire community and try to have it available for them to develop it, so...."*

Not being in the "Profession" or having an ongoing Stake: Informants who developed the innovations as part of the studio course worked on projects not directly in their own academic field, and usually did not wish to pursue the designs on a professional basis i.e. do not have long-term "goals aligned" with the project or to "make a living" from them. One exception to this pattern was an innovator who planned to setup a company to manufacture the design; for this reason he patented the designs and kept them private.

> *"We're not in a profession to, I wouldn't say profession ... but our aim here, the team's aim here is not to make a few tents and then mass manufacture it, and then sell it for this and to make a profit of this."*

> *"Well as myself, because of the stage of my studies or career I would leave it open just because I don't have the connections or the... goals aligned with this type of project right now. I suppose, say if I was doing my PhD thesis on this, then I would want to may be keep working on it then, things would be different."*

> *"But in general with this type of technologies what we're trying to do is to fill a social need ... in the most open view to keep it available. If it was the type of technologies where you think you can make a living out of it, then I think things could be different."*

A perceived Engineer Ethic towards independent design and IPR: When asked about open collaboration and peer-review, informants suggest that it simply did not occur to them in many cases and the institutional setting at MIT often reinforces the notion of working independently (or within the team) to sort out technical issues. This is often a result of an independent engineering mindset at MIT, sense of ownership in a team project with academic incentives to produce solutions within the team, and finally time-constraints pushing the team to solve the problem rapidly or conversely a lack of urgency contributing towards a closed team effort, preventing them from actively seeking external help.

> *"Its also Ego, its also us saying "hey we'll figure it out" and everyone of us in this institute has that … its also you know we probably have something in our heads that we haven't put on ThinkCycle and everybody says "what about this", you know its not done yet, it's a work in progress and everybody gets very defensive about their ideas."*

> *"Q: For example the Phase Change Material (PCM), one could argue that why don't you have 1000 brains look for a PCM instead of you yourself looking for it. One could argue…*
>
> *Yeah, one could. It never occurred to us. We could of course put something on the website saying, "If you have any ideas of PCM let us know", but its a team project. I mean now that you brought it up, I'd say well we'll figure it out – if we're under some time pressure, lets say come August, 3000 babies are going to just die, we'll so ok, but yeah…*
>
> *Q: So as a team project, you'd like the team to sort out these challenges within the team?*
>
> *These questions that you're bringing up, I mean we haven't thought about it, it hasn't crossed my mind to even put it up on ThinkCycle, to say "we're looking for this, let us know"."*

In addition, there is a notion that most engineers do not really wish to be concerned with the messy business of IPR, though we find later that others do indeed find themselves getting involved when their projects emerge "above the radar".

> *"ThinkCycle has 2 aims where one was the design process and one was IP and market test, market research etc. So there are several design engineers, me included, who would not want to even be bothered with the IP section of a project like this. And I'm in that category."*

Conflicts with seeking Broad Patents in Academia: One informant felt strongly that broadly applicable patents in academic settings was inappropriate, particularly if it prevented others in academia from freely pursuing research in that area. There was an inherent conflict of interest in patenting ideas directly related to ones own primary area of research.

> *"I don't think that academic environments should really be patenting very specific inventions that can be broadly used.*
> *…*
> *And again also, as I said before I don't think academic environments should really be patenting very specific products for anything, I guess maybe it's a little bit of a traditional view of IP but umm… I still feel uncomfortable about intellectual property in academic environments. It gets too close to conflict of interest, I think it's a little bit tricky to deal with.*
> *…*
> *In which (situation) I would patent? Yeah, I mean if I had, if I had, something which I thought was broadly applicable, I mean it wasn't going to be my direct research focus … then I think, and its not something that I feel would harm people's ability to do research, then I think that's something that's worth protecting… (which) I don't think it would be really useful in an academic context."*

There is an implication that the innovators could have published their work in academic journals instead of going the patent route, had this been in their area of academic interest or a greater awareness of such publications.

> *"Q: Alternatively if you had published this in the right journals or in the right medical community, do you think it would have had a similar or different impact?*

Umm, it's hard to say. And I don't know... there are probably design journals for medical technologies that we could have published this in... umm... but it's impossible to say how... umm... things would have worked out differently. I mean we, umm... we didn't know and we didn't have time to look into it."

Institutional Context, Culture and Support for Patenting

The decision to seek formal IPR such as patents often seems tied to the culture of the institutional setting at the time, i.e. the academic, corporate or collaborative partners involved. In the interviews we see examples of how each is perceived to influence the informants differently.

The role of the Technology Licensing Office (TLO) at MIT greatly facilitates the patent process, lowering the overhead (both financial and administrative) and perhaps increasing the incentive to file for patents. In addition, many departments greatly value patents filed which is often regarded as a metric for the quality of research conducted by other departments or funding agencies.

> *"In my case it was because somebody wanted to do it and the opportunity was there and there was not that much effort on my part to make it happen. So like MIT and this company really wanted it to happen and I just went for it. I don't think I would have pursued it myself independently."*

The nature of serious communication from external companies and lack of understanding of how to deal with IP, lead the team to seek help from the TLO.

> *"And so given the sort of lengthy detailed emails they were sending out, we decided to talk to the Technology Licensing Office (TLO). And that's what started that process.*
> *...*
> *We pretty much followed the TLO's lead. They instructed us in the process of patenting and documentation, and they took over all the negotiations with the company. So for us that was perfect, because we were all overloaded at the time with other thesis responsibilities, so for us it was the ideal situation to have what seemed to be a competent organization taking care of all of the legal stuff."*

There was a perception of TLO as a fair and competent organization the students can trust. Patenting through the TLO seemed to suggest a low-overhead option for the team, in that situation. However later the informants also recognized the amount of work involved in actually following through with a patent in terms of lots of paperwork and regular correspondence they must deal with (see the quoted dialogue on "Patents as Mystifying" in previous section).

In another case the patent was avoided after debate within the department. But it points out the low overhead required in actually filing a patent, and the financial support provided at MIT.

> *"So (co-inventor) was going to put together basically the technical information for the patent, and it was basically just be a no-brainer, but umm... (patent was not filed after debate with departmental IP Committee)"*

Was the default option provided to the team by the TLO to file for patents? One might wonder if the team was provided alternatives such as formal Open Source agreements legitimized and regulated by the TLO that may have been an appealing option as well.

Doing the project in the context of real-world collaborations with manufacturers and stakeholders in developing countries would clearly influence the nature of IPR adopted.

> *"The fact that we had no connections what so ever in a developing country during the design made it feel very much like an academic exercise, and sort of an isolated umm... intellectual exercise. So to make this a much more meaningful exercise to solve this problem, that would have to happen. So then, the questions of patent or Open Source would be answered by, would almost already be figured out by the people with whom we were working. So if the manufacturer who was interested in having this problem solved was amenable to the idea of Open Source then that's wonderful; my suspicion is that they would want some more exclusive right to the idea."*

However, another team finds that their decision to patent and license to a company makes them less open about their designs.

> *"Umm... so I've noticed that our relationship to our... the way we think about our designs has changed now that we've gone through the patenting. Whereas we're not as interested in sharing the ideas, just because we don't know what the restrictions are for the company who's licensed the design. Whether we're going to spoil things for them by talking about it."*

D. Role of Formal or Informal Social Contracts

Moderating the Transparency of Open Source Design: There is a desire to moderate the social contract for Open Source to take into account reciprocity, intentions, stake for future decisions and credit assigned among a distributed online community.

> *"Q: Do you think its possible develop a project in an open source manner and still patent. Do those things have any tension – can those things still work together?*
>
> *It will be difficult, umm... assigning where ideas comes from is what IP is about. And that isn't properly documented and understood in the historical way, then I don't think they're compatible. So Open Source to a point that the level of transparency needs to be moderated in some way.*
>
> *Q: Ok, what do you mean by that?*
>
> *Umm... for example if a group is working on a device and every idea is available, completely transparent, people can see everything but not necessarily contributing, that all the information is out there and you can't say weather its been released or not. In terms of moderating I think if you had a well defined understanding of who the contributors were for a project, and agreement on what the of the individual is as to their intentions with outcomes... if they're going to profit, it can't be... [garble]"*

One informant suggests the need for some form of "mentoring" agreement to allow students to trust the intention of external peers, however he also recognizes how that might detract some from participating.

> *"In an open community its harder to distinguish those intentions, so there could be people who are interested in just sort of siphoning off the innovations, but I mean that's the risk. So it could be that by having a mentoring agreement that could somehow deal with that, but again how many people are going to be turned off by the mentoring agreement and want to have nothing to do with the class. Some sort of understanding that you're there to assist the students but not to steal their ideas."*

Another form of agreement desired is one that allows people to use or license the designs with compensation, accreditation or respect for the original innovators. An aspect of the agreement would entail whether the IP would be shared among the contributors only or with the overall community / nonprofit entity hosting the online community.

> *"If I see an idea on ThinkCycle website and I have the resources to patent it and you (the inventor) don't do it after a year, which is the time limit, then I could do it right? Is that possible? Then that's a danger too. So maybe an agreement with the online community members to actually decide what you want out of the community, if you want to have maybe a personal patent or maybe a patent that belongs to the NGO?"*

> *"I would hope that in the future there are enough people who think to go to that site to search around for things of interest, such that a company who's in Africa can go there, see designs and if they want, hopefully there's some sort of, not as in the common sense, but some sort of a respect for the community where they contact they were interested in developing this and is there any way in which we can financially help, I mean maybe that's very idealistic as well, to just go off and create those designs."*

One informant suggested the need to setup an agreement to ensure part of the royalties from successful designs are set aside to support the ThinkCycle entity.

"They went down a very traditional route, the designs came out of the class and a company came and talked to them and then... (they patented) and basically ThinkCycle is, there's no formal arrangement to have nay money the generate come back to the organization, whatever it is. And so to me that seems a little bit like a bad precedent."

Would a nonprofit entity with appropriate IP and licensing arrangements provide incentives for innovators to avoid exclusive patents, in favor of copyright, GPL-like license agreements, pooled patents, etc. There is some indication that innovators would consider adopting a more open community-centric IPR approach if a legal nonprofit entity provided suitable arrangements and legitimate cover.

"If you patent things to MIT it may be hard for you to control what happens with the technology or with the idea, so if you have an online community that's based on a class at MIT that's not going to be complicated. But if you have a totally open source thing that's run as an NGO (nonprofit) then I would rather have everything accessible online. Oh but I guess the problem is if you don't patent it and publish it, then somebody else could do it right? If I see an idea on ThinkCycle website and I have the resources to patent it and you (the inventor) don't do it after a year, which is the time limit, then I could do it right? Is that possible? Then that's a danger too. So maybe an agreement with the online community members to actually decide what you want out of the community, if you want to have maybe a personal patent or maybe a patent that belongs to the NGO?"

What would be an appropriate social contract for IP (formal or informal) developed by a collaborative community online? How should a potential nonprofit entity administer such IP in a fair and legitimate manner to ensure both reciprocity to innovators and timely access to innovations for developing countries?

In the last section I outline the key desirable attributes for formal and informal IPR mechanisms and we will consider a framework within which appropriate policies, social contracts and incentives can emerge.

5.4 Emerging Patterns of Intellectual Property Rights in Collaborative Design

Based on the interviews, the 7 projects are categorized along 2 variables: 1) *level of public online disclosure* and 2) *the nature of intellectual property rights (IPR) desired*, as intended at the time of the interviews. Conjoining these two variables allows us to consider four main emerging patterns adopted by participants. In table 1 below, most cases fall within quadrants 1 and 4 (full disclosure vs. proprietary) which seems predictable, however two cases fall each within quadrants 2 and 3, which seems somewhat surprising at first. We will now examine the characteristics and rationale for why participants adopted these four patterns more carefully below.

	Informal IPR *(No intention to patent)*	Formal IPR *(In process of filing patent)*
Public Access *(Open online disclosure)*	▪ Hand Power Generator ▪ Low-cost Library ▪ Bio-sand Filter	▪ Cholera Treatment Devices
Private Access *(Restricted online disclosure)*	▪ Passive Incubator	▪ Low-cost Eyewear ▪ Smart-canes

Table 5.1: Categorizing 7 design innovations along a typology of four *IPR patterns* emerging from conjoining the level of online disclosure vs. nature of intellectual property rights desired.

The four emerging IPR patterns can be summarized as follows: (ordered by most public and informal to most restricted access and protected IPR)

A. Informal-Public IPR: The innovators develop the project in an open manner, disclosing evolving designs regularly online and seeking public peer review and contributions. At this stage of the design they do not intend to seek formal protection like patents (though this may change in the future given a one year deadline to patent). This approach seems most compatible with what are today considered "Open Source" principles in the software domain. However, the rationale for taking this approach with hardware is different in many cases here.

Among the 7 MIT studio projects, only 3 projects (less than half) adopted, what is generally considered an "Open Source" approach to their design process and IPR. This was surprising as the course instructors expected most teams to go this route, which had been emphasized throughout the course. We will now consider the key factors why some teams did indeed take this approach, before we examine why others chose not to.

Key characteristics of these projects:

- *No prior patents:* Neither of the informants of these projects had filed for patents in the past, though they are generally aware of patent issues and process.
- *Primary field of academics/research distinct from project area:* All informants had academic majors (Physics and Aeronautics) that were not directly related to the project areas they worked on. Informants stated that they did not have ongoing "connections or goals aligned with the project". Hence, as the project was not directly relevant to their core interests, they did not take a greater stake in it.
- *No plans to continue development:* All informants are graduate students who wish to focus on their own academic areas, and had no plans to continue working on the projects or in potential product development/business opportunities.

- *No sole ownership of designs perceived:* All informants inherited the projects from other individuals, who had either conceptualized the problem or the early designs. Hence, they did not feel ownership could be attributed entirely to them. This lack of direct ownership may have lead to a sense of responsibility to leave it in the public domain or not to take additional personal stake in the project.
- *Lack of team contributions:* The informants worked largely independently on these projects without other team members contributing regularly. Hence they frequently requested others to review their designs or postings online.
- *Patentability of technology unclear:* Though the projects were considered novel, most informants felt that additional work needed to be done to make a case for patenting the designs. However, one participant indicated that the design and prototype was fairly complete, but had debated and not clearly established whether it was patentable with faculty peers in his department.
- *Below the commercial radar:* The projects were not perceived as having high value in the market, hence under the commercial "radar". The informants felt the designs would be more valuable in pedagogical, research or nonprofit settings, and hence should remain accessible in the public domain.

B. ***Informal-Private IPR***: The innovators decide that the project should be made available in the public domain (eventually) and do not intend to seek formal IPR protection. However, they initially choose not to disclose the project designs publicly online, preferring instead to develop it further in a shared but restricted "private" online space.

Among the MIT studio projects only one team followed this pattern, Passive Incubators, however there is an indication that at least one other team (Cholera Treatment Devices) would have adopted this approach to some extent, if the facility for shared private online spaces had been available at the time. We will now consider the rationale for this seemingly contradictory approach.

Key characteristics of these projects and rationale:

- *Patentability unclear:* Informants were not entirely convinced if the concepts were novel enough or at a stage that they could be patented.
- *Patent inappropriate for target group:* A patent was considered obstructive for the target community of low-income end users in developing countries. Key concern was to make the innovations accessible to the community. Informants did not believe that patenting and licensing issues would be effective in this setting.
- *Perceived as "Team Project":* The informants worked closely within the group to strive to resolve the design issues; it was considered a "team project" for the course and they did not seek external contributions by the general public. Although they consulted many domain experts throughout the design process.
- *Preventing design from being "exploited":* Concern that the design could be "exploited" or misused if made publicly available at this stage. Wished to work out most technical issues before allowing a technical validation of the project, particularly with concerns for infant safety.
- *Need for Closed Working Space:* Informants claimed they did not wish to make the designs public until they had a "working device". Informants desired a "closed working environment" to "kick around ideas" before they are made available publicly. There was a sense that there should be freedom to make rapid design iterations without having to disclose all unrefined (or "stupid") ideas. The institutional setting and expectations for validated results may reinforce an attitude towards a keeping the design phase proprietary. They did not wish to detract expert reviewers from contributing, by exposing them to preliminary unrefined ideas.

C. ***Formal-Public IPR***: Innovators make their designs publicly accessible online, however they choose to file patents within one year of disclosure. This somewhat contradictory pattern is rarely seen in commercial settings, however it may be more common in academic settings though it is likely that some core design concepts may be kept proprietary.

Among the MIT studio project, only one case exhibited this pattern – *Cholera Treatment Devices,* which was somewhat unexpected by both instructors and team-members.

The rationale for open disclosure and then patenting include:

- *Seeking rapid adoption and impact:* The team selected the problem domain to have rapid and worthwhile impact, requiring broad access to the design so that it can to be adopted widely. For Cholera treatment in rural or relief settings, wide availability of such techniques was perceived to be more critical.
- *Learning through Design:* The informants pointed out that the design exercise was a learning experience for them, and they tried to document the project results as they would any research paper in academic settings. They did not initially seem to think of the project in terms of product development (and the notions of IPR that come with products), but more in terms of problem solving.
- *Concept emerges in the "Radar" of Commercial Interests:* The team took up patenting only months after the project was completed and disclosed online, as a means for addressing needs of companies, which contacted them. Previously the idea had been considered "under the radar" of commercial interests (i.e. unworthy or unimportant for commercial production).
- *Patent as enabler for Commercial Production:* The team felt the exclusive access to the IP through licensing the patent, would allow a company in the US the right economic incentives to manufacture and distribute the device.
- *Legitimacy of Patents in the Problem Domain:* The team seems to have realized that to make their concepts more legitimate for medical institutions or companies to adopt, the patent serves as a rigorous form of documentation in the public domain. It may provide a level of assessment and formal peer review that justifies other organizations to take the project seriously, particularly in the medical domain.
- *Patent Protection restricted to US market only:* The team only took up the patent when it was clear to them that the patent would only apply to the US and that the designs would remain openly available in developing countries.
- *Control over quality of design:* The team wished to retain some control over how the design was adopted by companies manufacturing it, primarily to ensure the quality of the product in addressing the critical treatment of Cholera.
- *Patent as recognized accomplishment:* Members of the team considered the patent a "privilege" and a form of public award that provided credibility and recognition among peers, companies and for future academic/job positions.

Key characteristics of these projects:

- Team consulted with many domain experts at Medical schools and hospitals. They made transcriptions of most such discussions available online. Hence there was an open-research oriented mindset as the project evolved.
- *Commercial Interests and Inquiries:* As the project began to receive inquiries from companies, the team began to consider how to formalize the IP to address these emerging needs, in conjunction with advice from the Technology Licensing Office at MIT (which clearly has a mission towards formal IPR arrangements).
- *No prior experience in patenting:* No members of the team had filed patents in the past; hence the notion of formal IP protection was not considered in the early stages.
- *Breakthrough vs. Engineering:* Informants did not consider the design ideas as major "breakthroughs" but rather "nice engineering". Hence the notion of patenting did not seem appropriate initially.
- *No disadvantage in keeping designs public:* The team did not perceive any disadvantage in leaving their designs publicly available online after patenting it.

Proprietary access was not requested by either the company licensing it or the technology licensing office.

D. Formal-Private IPR: Innovators choose to keep their IP under restricted disclosure, making the content available to a few selected participants only. At some point the innovators choose to file for patents to formally protect their IP. This pattern can be generally recognized as that which operates with most patentable innovations, which are not disclosed publicly until the patent is granted. Hence, for most innovators this may be considered the standard approach towards IPR.

Among the MIT Studio projects, we find that informants from at least 2 projects indicated their desire to adopt this approach in dealing with their IP, *Low-cost Eyewear* and *Smart-Canes for the Visually Impaired*. The instructors considered this approach the least desirable, as it seemed counter to the objectives of the course and toward sharing and learning outcomes. However, one must recognize the rationale for participants to adopt this approach to better understand some of the real-world constraints affecting them.

The most commonly cited reasons for doing so include:

- *Preempting Potential Infringement:* Preempting others from patenting the idea first to avoid future patent *infringement*.
- *Protecting from loss of revenue:* Preventing others from making profit on the innovation without adequate recognition and reimbursement to the innovator.
- *Control for Support, Profitability and Speed to Market:* Realization that product may be *highly profitable* in a commercial setting, and justifying the need to patent to help rapidly fund the product manufacturing and business development.
- *Scale above "sub-threshold":* Recognizing the *scale* of the implementation required to make project successful requires greater funding and control. Project is perceived as being above the "sub-threshold" for scale that it can be profitable on its own if developed well.
- *No Joint Contributions or Reciprocity:* As no one else seemed to be interested in contributing in the early stages of product development, the participants decided to abandon an open source approach and operate with restricted disclosure.
- *Compelling but Imperfect Technology:* Putting off field trials or public disclosure of an unfinished or imperfect technology to avoid "negating the technical evaluation" for future patent filing.

5.4.1 Summary: Trajectory of how IPR Patterns were adopted

A. *Informal-Public IPR*: Nearly all participants initiated their projects with this pattern in keeping with the general spirit of the course for open access of innovations to communities. At least 3 projects remained in this mode. These participants did not consider the projects directly related to their fields and did not have plans for continued development. They believe their projects are either unpatentable, under the commercial "radar" or require research or community involvement for continued development or long-term impact.

Subsequently at some stage of the project, a few participants chose to take one of several different paths:

B. *Informal-Private IPR:* Some participants felt the need for a closed working space to flush out the conceptual designs among the team and to refine the design before disclosing them more publicly at a later stage. These participants do not indicate that they have any plans for formal IPR. Conversely, other individuals take this approach since no one else seems to be contributing cooperatively to their projects; hence they abandon a purely open source ethic.

C. *Formal-Public IPR:* When solicited by a company, one team decided to undertake formal IPR protection by filing for a patent, while keeping their designs publicly available online. They feel a patent provides legitimacy in their problem domain and serves an as enabler for commercial production. However, they choose to patent under the condition that it primarily applies to the US market, leaving their design accessible in developing countries.

D. Formal-Private IPR: Finally, some participants who chose to keep their designs in a closed working space (pattern B) decide that their projects have emerged above the commercial "radar" or "sub-threshold" and may have potential for profitability. They choose to keep all design proprietary and pursue patent filing, to preempt potential patent infringement, loss of revenue or credit, and avoid "negating the technical evaluation" by public disclosure of their unfinished technology. These participants also take a greater stake in the continued development of the product and its implementation in the field; hence they wish to have a greater level of control and leverage from the IP.

This evolving trajectory can be summarized in the table below:

	Informal IPR *(No intention to patent)*	Formal IPR *(In process of filing patent)*
Public Access *(Open online disclosure)*	1 **A. Open Source** → 4	**C. Public Patent**
Private Access *(Restricted online disclosure)*	↓ **B. Closed Source** 2 → 3	**D. Proprietary Patent**

Table 5.2: Trajectory of how innovators adopt different IPR patterns (A-D) at various stages of their design process (1-4) over time. Note that some participants remain within stages 1 or 2.

Hence the 4 main trajectories among these patterns are:

1. Maintaining the project as *Informal-Public IPR* (a form of Open Source). Most participants start here, while some (less than half) remain within this pattern.
2. Keeping the project within a team with *Informal-Private IPR* (Closed Source), disclosing some design publicly outcomes over time, but with no intention of patenting in the future.
3. Restricting the disclosure of the design process to a private online space and then seeking patent filing. The designs remain proprietary until the patent is granted.
4. Going from a publicly disclosed project with informal IPR to that of formal IPR with a patent filing, while continuing to disclose the designs publicly online.

Key episodes that triggered changes in adopting specific patterns include:

1. *Pedagogical context of open collaborative design studio* – the nature of the class with an emphasis on socially-motivated problem solving and open source principles, would have motivated many to initially adopt a *Informal-Public IPR* pattern for their projects. Participants feel that designs remain under the commercial "radar" and are most valuable in their current state, if accessible within pedagogical, research or nonprofit settings.

2. Design teams or individual innovators (working alone) switch to *Informal-Private IPR*, under two different conditions: (patentability of the designs may be unclear at this stage)

2.1. *Perceived need for closed working space among design team:* As a design team begins to flush out many unrefined and alternative design iterations, they choose to setup a closed online working space, particularly if there had not already been much external public contribution in the design process. There is also a concern that the preliminary project concepts may be used inappropriately ("exploited") or misjudged.

2.2. *Lack of reciprocal contributions:* In some cases, innovators will go "closed source" if they do not feel that their project is eliciting much interest among the general public, such that no external contributions are being made. In their minds this violates the principle of a cooperative open source project, with a lack of reciprocity i.e. they put ideas in the public domain without reciprocal contributions towards its ongoing development.

3. *Recognition that a project is above "sub-threshold":* Innovators at a certain stage of the design cycle, recognize that 1) the technology is novel and patentable, 2) the product may be highly profitable in (first-world) commercial settings, 3) the scale of the project requires greater product development, funding and control for maximally fast implementation, 4) they take a personal stake in the continued product and business development. This justifies for them a *Formal-Private IPR* pattern to maintain the designs as proprietary for greater leverage and control, at least until patents are granted. It is expected (from the interviews) that most participants would make designs publicly accessible after receiving the patents (i.e. moving into pattern D).

4. *Solicitation for licensing by commercial entity:* Participants operating under an *Informal Public or Private IPR*, when faced with a serious commercial interest seek some means to formalize their IP. Most cases so far do so by filing for patents, while others may choose to adopt copyright or release a formal publication. Either of these options would give them a public recognition over their informal ideas and enable to them to pursue licensing options with the commercial interests. However, some of these participants continue to keep the designs under public disclosure as they are covered by the patents and do not wish to take greater stake in its development to assert additional control over the IP in developing countries. Hence they adopt a *Formal-Public IPR* pattern.

Hence patterns A and C can be considered steady states, which are eventually adopted by participants even if they choose to keep the ideas proprietary during the design process.

5.5 Formulating New Frameworks for Intellectual Property Rights

5.5.1 Key Attributes and Incentives for IPR in University Settings

The interviews with informants suggest a number of key incentives and attributes that emerge in their notions regarding IPR. Before we consider whether either patents or Open Source approaches are more suitable mechanisms, we must examine the nature of such perceived incentives and attributes to inform a wide array of options regarding IPR, both formal and informal. Any solution proposed ought to consider how such attributes may be addressed or intentionally relinquished to support the IPR goals desired.

I. **Recognition:** A key motivation for innovators is to provide some kind of legitimate recognition in the form of public tribute, award, publication or credit for their work. Open Source often falls short in that it does not provide a direct and immediate public recognition, while patents retain such a stature. Special awards, publications and credit mechanisms play an important role to encourage innovators, particularly in critical problem domains that do not receive much attention from either industry or academia.

II. **Control:** An overwhelming rationale for seeking formal IPR is attributed to having some level of control over how the ideas are utilized by others, in terms of appropriate usage, quality of production, leverage to negotiate terms of use or access, and ability to commercialize if needed. It is often assumed that simply filing for patents provides this notion of control, however the nature of licensing agreements and institutional support truly enables one to negotiate such terms. Strengthening the licensing and institutional support for innovators is an important aspect to emphasize in any IPR approach.

III. **Preemptive Protection:** Innovators have a desire to prevent others from unfairly staking claims to their design concepts, and in effect risking infringement on their own work. Mechanisms such as patent filing, research abstracts, or publications play that role. In addition, legitimate online registration of one's idea and public awards may also provide accreditation and counter such infringement claims. Prof. Anil Gupta [2000] has suggested a global registry to protect grassroots innovators. Using an online system like ThinkCycle to archive ongoing design ideas can also provide a legitimate "paper trail".

IV. **Commercial Enabler:** Many innovators seek to have their designs go into production such that they can be more readily accessible or subsidize expenses for access in developing countries. There is concern that without legitimate patents and exclusive licensing, companies will not find it competitive or profitable to manufacture their innovations. Such market dynamics differ in the Open Source software industry, however it is an important consideration with respect to hardware products. Any IPR policy must enable above "sub-threshold" innovations to receive legitimate licensing and institutional support to encourage commercial production. Alternatively, community-based or nonprofit production and distribution mechanisms could also be explored and supported e.g. for low-cost or locally produced agricultural, health and emergency relief technologies.

V. **Real-World Legitimacy and Learning:** Informants felt it important to gain familiarity with the process of dealing with IPR issues in real-world settings i.e. doing prior art search, creating technical drawings and patent filing – as such tasks were considered natural part of designing products. Clearly such aspects should be emphasized in the design and learning process regardless of IPR approach adopted. In addition, many informants felt that gaining formal IPR such as patents gave them legitimacy and leverage while talking to companies, organizations and faculty peers. Hence, legitimate recognition plays an important role in supporting innovations to move beyond academic settings to the market.

VI. **Unfettered Access for Target Community:** All informants strongly intended for their innovations to be easily accessible by the target users or producers in these settings.

However, their approach differed depending on the level of stake they assumed in carrying it further (usually with restrictive disclosure) or leaving it for others to continue developing (keeping it publicly accessible). This intention to provide maximal access to the target communities made the deferred and territorial scope of patents an appealing option. Alternative IPR arrangements must support at least such access conditions.

VII. **Moderating Transparency of Public Access:** There is a desire to moderate the level of disclosure of ongoing ideas at various stages of design to selected individuals or groups. In many cases, informants wish to have a "closed working space" to selectively share only well-posed designs publicly while being able to "kick around ideas" informally among the group. The institutional setting and expectations for validated results reinforces an attitude of gradual moderated disclosure and than fully transparent access. It is important to find ways to support such moderated transparency in the online design tools and IPR policies e.g. allowing publication of design abstracts rather than full disclosure.

VIII. **Social Reciprocity for Cooperative Sharing:** The apparent transparency of Open Source implies some level of cooperative design contributions or peer-review. In the absence of such reciprocity, innovators may not feel much incentive to continue to openly disclose their evolving ideas in a public online forum. There is a need for some form of formal or informal agreement, a social contract, allowing innovators and potential contributors to agree to terms of access, accreditation and outcomes. The use of GPL-like licensing agreements in the Open Source software community clearly play this role; however one must consider if and how such formal agreements should be setup for collaborative hardware design. One example is the Simputer General Public License (SGPL)[59] that must be examined carefully in the context of online projects on ThinkCycle.

IX. **Demystifying the IPR Process:** To be effective any set of IPR alternatives must ideally support several key attributes for both innovators and adopters: 1) easy to understand, 2) low-overhead to setup and implement, 3) affordable, 4) appear to be fair and reciprocal, 5) clear outcomes of the policy if adopted, 6) enforced and legitimized by an impartial, competent and recognized entity. The interviews suggest that the patent process is both generally overwhelming for innovators and yet has lower barriers for entry in institutions like MIT (with the support of the TLO and incentives from MIT departments). Conversely, formal IPR policies around Open Source are not well understood by innovators or supported by the institution, even though open sharing is implicitly encouraged. Hence there is a role for the institution and potentially intermediate entities (a recognized nonprofit entity administering such IPR) to provide awareness, consultation and actively support a range of IPR policies appropriate under different settings.

X. **Institutional Support:** In my mind, the institutional setting and support (implicit or formalized) provided to innovators has the greatest influence on the nature of IPR adopted. The interviews suggest that the institutional setting at MIT promotes a spirit of open sharing, socially responsible action, and rigorous validation of results. However the same setting also legitimizes formal IPR approaches like patents and actively supports students and faculty in filing patents. Conversely, there is little if any formal support for alternative mechanisms like Open Source, though a great deal of debate on openness in academic, pedagogical and research programs is beginning to emerge at MIT. Hence, the institutional policies and case examples have a strong role to play in shaping both the dialogue and nature of IPR adopted by its members in any university and research setting. In addition, there is a role for intermediate entities that can inform, administer, and support appropriate IPR policies. To be effective, such entities must be setup with legitimate recognition and support in industry and academia.

[59] http://www.simputer.org/simputer/license/

5.5.2 *Supporting Formal and Informal IPR for Critical Innovations*

The outcomes of this preliminary study indicate the role of both formal and informal IPR mechanisms to support innovations in university settings. I quickly outline several approaches that I feel are important to consider, based on the framework cited in section 1.5 and the incentives emerging in this study: *(this is a draft outline that must be refined and expanded)*

- ***Institutional Support*** for an array of IPR options such as Experimental Use, Patents, Copyrights, Open Source, Patent Pooling etc. There should be an emphasis on awareness and education as well as supporting various licensing arrangements to ensure fair and timely access. In addition to the Technology Licensing Office, there is a role for other entities within the institution to provide awareness, education and support.

- ***Awards for Innovation in Critical Domains*** play an important role in providing legitimacy to such an area as well as recognition and incentives for maintaining more of the design concepts in public domain. There is a strong need for MIT and other leading industry, academic and government institutions to support such awards, not unlike the Pulitzer Prize in literature and the Fields medal in mathematics.

- ***Forums for Publication of Research*** such as conferences, journals, newsletters etc would encourage alternate means for publishing IPR in critical domains. The *"development by design"* conferences[60] are a step in this direction; it is currently being expanded to support an international committee of experts for peer review and publication of the proceedings in the ACM Digital Library for greater legitimacy. In the future appropriate peer-reviewed Journals and online abstracts should be introduced.

- ***Licensing Arrangements for Cooperative Product Design*** must be carefully considered in online systems such as ThinkCycle to provide greater trust and reciprocity for product development and IPR outcomes. Such agreements (similar to the SGPL) should be setup online in a simple and clear manner with low overhead to participate. This is not unlike similar arrangements on Open Source software repositories like *SourceFourge.net* and *Savannah*[61] maintained by the Free Software Foundation.

- ***Moderated Online Design Spaces*** that support closed working areas for the teams while allowing them to share evolving designs publicly as needed. *Private ThinkSpaces* are already provided on ThinkCycle, with the option to publicly disclose selective content.

- ***Online IP Tracking for Open Collaborative Design*** would allow individuals and teams to maintain a "paper-trail" of the evolving design concepts, and enable future patent filing or preemptive protection against potential patent infringement claims. A form of such a mechanism is already in place on ThinkCycle, however with greater peer-review and additional legal aids it may prove to be a more legitimate mechanism for innovators.

- ***A Global Registry for Critical Design Innovations*** administered by legitimate entities and international experts, would provide an alternative to patents particularly for the small-scale "sub-threshold" innovations that wish to remain in the public domain. It would provide peer-review, paper trail for preemptive protection, and spur interest in the innovations globally. Similar approaches for grassroots innovators have been suggested by many scholars including Gupta [2000]. One needs to carefully consider how such a global registry should be setup and administered to provide the most suitable outcomes. A nonprofit entity affiliated with worldwide organizations could operate such a global repository, to ensure legitimacy, legal cover and assistance for innovators. Alternatively the US Patent Office could consider setting up a similar initiative within its mandate, as an alternative pre-publication or registry for small innovations in critical domains.

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[60] http://www.thinkcycle.org/dyd02

[61] http://savannah.gnu.org/

6 CONCLUSIONS: RETHINKING COOPERATIVE INNOVATION

The thesis began with a critical challenge: *"How should we create an environment that supports global interdisciplinary cooperation towards open design innovation in critical problem domains?"* I suggested that there is an urgent need today to expand the mandate for cooperative R&D in sustainable development and design to ensure greater support for, what I consider, *Universal Human Rights*. The Appropriate Technology movement in the 1970's pioneered radical thinking towards localized, sustainable and socially motivated design innovations, however the movement had limited impact as it failed to mobilize both local and global organizations, industry and the research community in bringing worthy innovations from concept to market. Several emerging trends and conditions today including networked computing and distributed collaboration, renewed interest in sustainable development and greater openness in intellectual property rights, allow us to consider novel approaches towards globally-relevant problems in critical domains.

In this thesis I have suggested that sustainable design innovation can benefit from multi-disciplinary cooperation among diverse organizations and experts facilitated by online platforms, studio design courses, peer-reviewed publications in conferences and novel intellectual property models. The thesis work was grounded in a three main areas of research: *Cooperation, Community* and *Intellectual Property*. The key principles and assumptions embodied within these themes were further explored in the thesis research, while several conflicts and challenges emerged during this process.

ThinkCycle: Open Collaboratory for Sustainable Design Innovation

The ThinkCycle initiative began at MIT in 2000 with a modest goal of archiving well-posed challenges and ongoing design solutions in an online database, for use by faculty and students conducting real-world projects in university engineering courses. A collaborative online system was developed to provide community tools and shared spaces for students, domain experts and stakeholders to discuss, exchange and construct design solutions in critical domains. ThinkCycle continues to grow as a distributed community and open public domain site to support ongoing cooperation, peer review and global dissemination of innovative ideas in sustainable design.

The key challenges and questions for this thesis research are summarized as follows:

- Understanding the role of collaborative online platforms for distributed design and problem solving in critical domains. How should such systems be designed to be scaleable and support the diverse needs of users worldwide? What are the key social and technical challenges for sustaining a distributed online community?

- How can we develop design curricula and linkages with real-world problem domains to provide university students with opportunities for research and working experience in sustainable design and development? How can communities of practice emerge from co-located or distributed design teams, domain experts and stakeholders? How should online platforms support the needs of such communities of practice?

- While an online system may allow distributed participants to cooperatively develop design innovations, how do innovators deal with the resulting intellectual property concerns? What are the social incentives and conditions that change the nature of protection and dissemination of individual and cooperative design innovations? What are the emerging intellectual property patterns and how can they be better supported?

Clearly many of these questions cannot be fully evaluated within the limited scope and timeframe of the thesis work, however even within such a limited setting I believe insights and concerns have emerged, which must be carefully considered in future research, particularly as the initiative is scaled-up beyond university settings. In this concluding chapter, I summarize the principle lessons learned and open research directions for future work.

Developing Online Collaboration Platforms

The design of the ThinkCycle online collaboration platform has evolved through several stages of system design with ongoing user feedback over a period of 16 months. The system remains primarily structured around topics or problem domains of interest, which serve as community knowledge repositories in areas of sustainable design. Within topics, there are online project spaces (or ThinkSpaces) 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.

ThinkCycle provides an open digital library for peer-review and publication of papers submitted to the international *development by design* conferences. In addition to the structured online forums for collaboration, content archiving and knowledge dissemination, ThinkCycle supports informal modes for discussion, peer-review and interaction. While the early prototypes demonstrated the basic concept, a functional and robust system required a great deal of software engineering and iterative system design before there was sufficient user adoption to gain critical mass (by mid-2002). The system has gradually evolved from an online information archive to an online platform for distributed communities engaged in cooperative design. ThinkCycle now has nearly 2000 registered members who have contributed hundreds of content postings, reviews and discussions in dozens of Topics and ThinkSpaces created on the site.

While the software system and online community continues to expand, a number of critical insights and challenges have emerged:

- Though an online system must provide sophisticated functionality for collaboration and community tools, it must also match user expectations of simplicity, ease of use and integration with existing forms of communication like email.
- Asynchronous design interactions and searchable online archives complement face-to-face synchronous work among localized groups. However speed of access in low-bandwidth settings and need for regular design updates must be addressed with lightweight web and email-based solutions and asynchronous client tools for access and uploading designs, which do not require continuous web connectivity.
- The need for structured interaction vs. informal social mechanisms must be carefully balanced to design a system that allows users structure and flexibility to browse and contribute diverse forms of content and support open dialogue in a sustained manner.
- Social norms and conventions among communities of practice emerge over time. Any cooperative system must provide sufficient flexibility for such norms to shape the overall nature of the community, while one must recognize the norms imposed by its own design.
- Product design is a social process; hence social mechanisms for awareness, access and iterative design among local or distributed participants must be supported.

The greatest challenge for a novel online platform like ThinkCycle has been proactively dealing with the *ongoing co-evolution of system design and user expectations.* While the ThinkCycle architecture and applications have grown extensively over a span of 16 months, the level of adoption and ongoing usage by an online user community has somewhat been slower. An online community platform must be robust and provide a few distinctively useful features at the onset, for lead adopters to readily embrace it and actively sustain its usage, encouraging others to join. Design of extensive content structure and interaction mechanisms must be carefully balanced with user expectations and interests. A small-scale lightweight system that grows its structure and interaction protocols over time, with ongoing usage and feedback from the user community has a better chance of being adopted more readily. This requires great attention to users needs and emerging requirements, while developing a flexible underlying architecture so that the system and its interface may be adapted more easily. After several design iterations, the ThinkCycle online platform has evolved to meet most user expectations for functionality, robustness and scalability, though the high-level structure and interaction requires some familiarity for novice users. Overall, it appears that the design of a large collaboration system must evolve gradually with the needs and interests of its distributed online community, while continuing to explore innovative applications and novel interaction mechanisms.

Establishing Sustainable Design Curricula in Universities

As part of the ThinkCycle initiative a global network of studio design courses were conducted at MIT as well as universities in India, Brazil, Kenya and Portugal. Faculty and students in these courses worked with stakeholders in the field and domain experts in industry to develop socially relevant design innovations. Several projects from the MIT studio, *Design that Matters*, have been patented or licensed, while two projects received MIT IDEAS and Lemelson Technology awards in 2002. One project on Low-Cost Eyewear won the Collegiate Inventors Award and is being commercialized by a startup venture with graduates from the Harvard Business School.

I developed the online collaboration platform while I co-taught studio courses focusing on sustainable design at MIT in 2001 and 2002. To examine the nature of collaborative design, learning outcomes and social attitudes of students participating in such studio courses, I initiated a study consisting of online surveys, intensive interviews and case studies of design projects.

Online surveys and interviews were conducted with 17 students who participated in the spring 2001 and 2002 studio courses at MIT. The study provides a qualitative assessment of student attitudes towards learning and collaboration in this setting. The responses suggest a number of key themes for studio courses: 1) courses focusing on sustainable design through hands-on learning have a broad appeal among students, 2) an important element of such real-world design courses is establishing meaningful linkages with external domain experts and organizations, and providing students opportunities for fieldwork, 3) the success of such courses requires commitment from faculty to provide academic legitimacy and active involvement of instructors and domain experts in mentoring group projects.

For online collaboration platforms, the responses indicate: 1) online tools focusing on sustainable design are useful for sharing and archiving designs, and have a role in dissemination and problem solving however they are most valuable when teams or domain experts are not always co-located, 2) the overhead for usage by busy engineering students must be minimized by simplified interfaces and greater integration with existing channels of communication like email, 3) in addition to improved navigation, many users requested tools for *asynchronous content updates* and *real-time chat*. Overall responses suggest that users view design as a *social process* rather than only that of archiving and exchanging data.

Another successful studio course was conducted by faculty among several schools in Bangalore, India. Interdisciplinary teams developed several design concepts and working prototypes related to household composting, rainwater harvesting and energy efficient stoves. While the Bangalore students used ThinkCycle to archive some project-related work and publications, there was distinctly lower online usage observed. The primary reasons seem to be lack of ongoing high-bandwidth connectivity in the schools, unfamiliarity with the online platform, lack of remote peer-review community and most importantly a preexisting culture of face-to-face design interaction. No formal study was conducted with the Bangalore students as their course was only completed in December 2002, however detailed assessment by faculty and students in the future would reveal greater insights into the nature of design interaction, online usage and learning outcomes.

It is important to recognize that the learning and cooperative design outcomes of such applied studio courses cannot be easily quantified. In different settings, the culture of pedagogy, design process, linkages with field organizations and educational objectives dictate the nature of design outcomes. While some general curricular materials, standards and objectives can be adopted among different schools and universities, I believe design curricula must be carefully developed by faculty within the culture and environment of the pedagogical setting and localized problem domains. However, we have encouraged faculty and students across schools to share and peer-review experiences from design projects through the online platform and by submitting publications to the *development by design* conferences. Participation in ongoing workshops, working in shared problem domains and cooperative design projects among schools will encourage greater learning from diverse studio courses on sustainable design held worldwide.

Understanding Intellectual Property Rights in Open Collaborative Design

With the emergence of ongoing design projects on ThinkCycle, one finds a variety of seemingly perplexing or contradictory attitudes and approaches towards dissemination and protection of design innovations. As part of the thesis, I conducted a study to examine the social perceptions of property rights and nature of IPR policies adopted among product innovations in university settings. I examined 7 case studies of product innovations from the *Design that Matters* Studio course offered in spring 2001 and 2002. Intensive interviews were conducted with 10 students from the studio course, while additional interviews with 3-4 university researchers were also conducted to validate some of the findings. The outcomes from these interviews inform the analysis of IPR for open collaborative design. There is an opportunity to develop novel mechanisms that support multiple views of IPR for greater innovation in critical problem domains.

The preliminary analysis suggests that despite the ambiguity surrounding property rights among student innovators, they seem to have clear and strong rationale for dealing with IPR questions. There are diverse and reasoned notions surrounding patents, suggesting many important attributes that informants seek such as recognition, control, learning, preemptive protection and enabling commercial production of their work. However, there is surprisingly greater ambiguity and skepticism about Open Source policies, being regarded as noble or academic exercise rather than an operational IPR policy. All informants are not clearly convinced that Open Source policies can be adopted in hardware design, and there is a sense that the social reciprocity of cooperative design is not always emphasized in the process. However for many participants working on design innovations in sustainability areas, Open Source represents the normative approach that is initially adopted. Several factors influence changes in IPR approaches adopted by innovators, including 1) recognition of innovations as being "under the radar", 2) deferred or territorial scope of patents, 3) institutional biases and stakes in the project and 4) the role of formal or informal social contracts.

In examining the 7 projects in the study I find them aligned within a typology of four emerging IPR patterns based on level of public disclosure and formal/informal nature of IPR desired. In the thesis I describe the key characteristics and rationale for adopting each of these patterns.

- *Informal-Public IPR:* This is essentially a form of Open Source dissemination online, though no licensing mechanism is adopted. Most design projects on ThinkCycle are initiated in this pattern and at least a third of them remain in such status, primarily because the project is subpatentable or innovators have low stakes in the outcomes.
- *Informal-Private IPR:* Many innovators choose not to reveal all ongoing design experiments publicly until they have validated their findings. Hence they maintain contributions in private shared online spaces, while not seeking formal patents. Unless aspects of the designs are gradually disclosed, this IPR pattern can be considered the most extreme form of protection i.e. a Trade Secret.
- *Formal-Public IPR:* Some innovators when approached by companies to license their design innovations may choose to patent their work, even if previously disclosed, as long as it is within 1 year of disclosure. Innovators argue that by patenting, yet keeping innovations public they provide companies incentive for manufacture while being able to retain some control over the quality, specifications and usage of their innovations.
- *Formal-Private IPR:* A few innovators choose to keep their design concepts under private access, while seeking patents. This is primarily done when innovations are considered patentable and "above the radar" of commercial interests, such that protection becomes important. These innovators also wish to take a greater personal stake in the outcomes.

Innovators find themselves moving among these patterns over the lifecycle of a project, based on the nature of design outcomes and emerging patentability or personal stakes desired in an innovation. Hence we must consider the incentives and mechanisms that support diverse models of intellectual property rights, particularly among distributed participants of cooperative innovations.

Several approaches and policies that can be adopted to support both formal and informal IPR for critical design innovation, summarized here:

1. Considering institutional support for diverse IPR models (particularly in universities).
2. Establishing prestigious awards for sustainable design innovation.
3. Creating forums for publication and peer-review of research in sustainable technology.
4. Supporting online project design spaces with moderated access, like ThinkSpaces.
5. Maintaining a digital "paper trail" of design contributions from distributed participants.
6. Establishing a global registry for subpatentable innovations, as an alternative to patents.
7. Creating novel and flexible online licensing mechanisms to support diverse IPR patterns.

Overall, the study of social attitudes and incentives towards intellectual property models is a fascinating and productive area for ongoing research. I believe neither Open Source nor Patents are an appropriate solution for all design innovations developed online, however a range of mechanisms that provide varying attributes and incentives from both, need to be considered. Key insights and novel models developed on ThinkCycle must be carefully assessed and implemented, such that some generalized approaches for collaborative design in distributed online settings may emerge.

Future Work: Expanding Cooperative Innovation in the Commons

Increasingly as many more design projects emerge with ThinkCycle, particularly ones spanning institutional boundaries with participants worldwide (not unlike the open source software movement), a number of critical issues must be resolved to support innovation:

- What technical and social mechanisms allow academia, industry and the nonprofit sector to cooperate in sustainable design projects, while ensuring mutual benefits?
- How can design teams with participants from multiple institutions and geographic regions cooperate, manage, exchange and resolve the design process and property rights?
- What kinds of social contracts and licensing schemes support cooperative innovation, while providing open peer review, protection, dissemination and ability to commercialize?
- How can small-scale or subpatentable innovations be documented, disseminated and commercialized through a global registry with network of companies and entrepreneurs?

To address these questions, I would propose setting up experimental design studios spanning several universities worldwide. Design faculty from each institution could run the courses, along with the participation of selected Non-governmental Organizations (NGOs) in developing countries, and local industry partners. Up to five problem domains would be selected and student/expert teams will be formed across institutional boundaries with geographically dispersed participants. There would be some shared lecture sessions, as well as opportunities for face-to-face interaction in workshops or joint fieldwork. Participants would be urged to exchange and peer review designs using ThinkCycle online platform and collaboration tools.

In preparation for the collaborative studios, we would expand the online design tools, gather sustainable design curricula and case studies/projects for the design teams, setup industry and nonprofit linkages in specific problem domains, and institute a variety of IPR mechanisms for sharing and protecting their design innovations. This pilot experiment would reveal the challenges for distributed collaboration in product design, nature of learning and patterns/conflicts in models of IPR adopted by different participants. One can also examine strategies for field deployment, dissemination of results as well as private entrepreneurship and commercialization.

The key questions to study would include: 1) the benefit and limitations of online platforms in the design process, 2) the role of industry and nonprofit partners in the design outcomes, 3) the conditions under which certain cooperative design projects fail or succeed, 4) approaches for integrating sustainable design collaboration in university curricula, 5) the IPR policies that ensure the appropriate balance between protection and sharing among participants, and 6) effective mechanisms for field deployment, dissemination and commercialization of designs. Studies would be conducted in several stages, using online surveys, intensive interviews, analysis of online design interactions and deployment of design innovations developed by distributed participants.

Over the past two years, students taking the *Design that Matters* studios at MIT and Bangalore have developed many sustainable innovations, which have been field-tested, patented and licensed, while one is being commercialized by a startup venture. Clearly such initiatives may continue to yield socially relevant design solutions and novel product innovations. However, these innovations must be supported in terms of field-deployment, entrepreneurial assistance, industry partnerships and suitable models for intellectual property protection and licensing.

Each year thousands of small-scale design innovations developed worldwide lack appropriate expertise and resources for evaluation, field deployment or commercialization. The research conducted in these university settings should allow one to help develop appropriate frameworks that support cooperative innovation between academia, industry, the nonprofit sector as well as grassroots innovators. ThinkCycle is emerging as a collaborative platform, open design repository and global community for innovations in sustainable design. Over the next few years it may be beneficial to further develop this initiative as a nonprofit entity, the *ThinkCycle Foundation*, dedicated to supporting distributed cooperation in sustainable innovation, and new models of education, intellectual property and product deployment. Ongoing conferences like *development by design* provide a global forum for educators, researchers and practitioners to create a supportive community in critical problem domains.

In this thesis I have argued for expanding the scope of cooperative R&D towards sustainable design innovation to ensure Universal Human Rights. As part of the thesis research, I have outlined the critical challenges, implemented concrete approaches and conducted studies to better understand the social nature of resulting outcomes. Through such initiatives one can continue to develop architectures, platforms and models for distributed collaboration, support communities of practice in global problem domains, and conduct research on novel intellectual property mechanisms to support cooperative innovation in the commons.

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APPENDIX

Online Questionnaire for Study on Collaboration and Learning

A study was conducted on collaborative design and learning in the MIT design studios held in 2001 and 2002. As part of this study participants were asked to answer questions in an online survey and intensive interviews. This is an early version of the 5-part online questionnaire with 60 questions. For many questions, a 5-7 point *Likert scale* was used to provide a series of statements to which participants could indicate degrees of agreement or disagreement (shown as 1-5 below). After a pilot test, the online survey was revised; some questions were refined and 20 additional questions were added to the new online survey (not shown below).

A. Demographic Information

1. Current Academic Status (Undergrad, MS, PhD, Graduated)
2. Degree Major
3. Age
4. Gender

B. General Attitudes towards Collaboration and Course Projects

5. I prefer to work independently on assignments and projects than in groups. (rate 1-5)
6. I feel that working with others on assignments and projects is more helpful than working alone. (rate 1-5)
7. The last time I was involved in a group project, I was found it to be an enjoyable and worthwhile experience. (rate 1-5)
8. I view the field of my design project as intensely competitive. (rate 1-5)
9. I don't want to share my project designs openly, because others may use it without much credit or benefit to me. (rate 1-5)
10. I don't want to share my project designs openly, because my ideas are too premature for others to review. (rate 1-5)
11. I don't want to share my project designs openly, because it takes too much effort to do so. (rate 1-5)

C. Course Evaluation (only applicable to participants in studio courses)

1. Why did you decide to take this studio design course?
2. The course exceeded my expectations for what I had hoped to learn? (rate 1-5)
3. The course significantly changed my approach towards socially conscious design? (rate 1-5)
4. The course provided me with valuable experience and skills for real-world projects. (rate 1-5)
5. The course gave me a very good understanding of the problems and challenges in designing appropriate technologies in the real world. (rate 1-5)
6. I found the instructors helpful in teaching and mentoring projects. (rate 1-5)
7. I found the guest speakers engaging and insightful. (rate 1-5)
8. I found the student peer-reviews and collaborations helpful towards my project. (rate 1-5)
9. I found my interaction with external domain experts and organizations, during my project to be very productive. (rate 1-5)
10. Rate your learning experience in this course relative to other project-based design courses you have taken. (rate 1-5)
11. I felt that doing the projects for this course was a frustrating and unproductive experience. (rate 1-5)
12. I wish to seriously continue working on my project even after the course is completed. (rate 1-5)
13. Rate the difficulty of this course relative to other project-based design courses you have taken. (rate 1-5)
14. Rate your attendance and participation in the class sessions. (rate 1-5)
15. I consider this course to be very time-consuming. (rate 1-5)
16. How many hours a week on average did you spend on this course outside class? (less than 5, 5-10, 10-20, 20-30, more than 30)
17. I consider this course to be intensely competitive. (rate 1-5)
18. I recommend this course be offered as part of the university curricula for credit to all students in the future. (rate 1-5)
19. What were the best outcomes of this course for you?
20. What suggestions can you make to improve the course?

D. Access and Experience with Online Tools

21. How would you rate your proficiency with the Internet? (novice, casual, experienced, expert)
22. Where do you access the Internet most frequently? (home, campus, work, public places, other)
23. Usually how fast is your Internet connection? (slow and unreliable dialup modem, fast dialup modem, cable/DSL service, high-speed T1 line)

24. How often do you access the Internet? (several times a day, once a day, once a week, every month)
25. How often do you check your email? (several times a day, once a day, every week, every month)
26. How often do you use instant messaging or chat? (never, several times a day, every week, rarely)
27. Have you used any web-page authoring or online collaboration tools before? If so which ones?
28. Have you created your own websites or web pages? If so, please list some sample URLs here.

D. Attitudes towards using ThinkCycle (only for participants using ThinkCycle)

Basic Usage and Usefulness

1. How often do you visit the ThinkCycle site? (several times a day, once a day, once a week, every month, rarely)
2. Do you believe this online platform is a useful tool? (rate 1-5) If so Why?
3. What aspect of this platform do you find most useful? (open-ended)
4. Did you find the tool very complicated or confusing to use? (rate 1-5)
5. Did you find using the tool very time consuming? (rate 1-5)
6. What aspects do you find most difficult, confusing or time consuming to use? (open-ended)
7. Did you find it necessary to review the ThinkCycle tutorial? (rate 1-5)
8. Did you find it necessary to ask the instructors or peers how to use ThinkCycle? (rate 1-5)
9. When did you use ThinkCycle most often during the course? (open-ended)

Reviewing Content

10. I find that viewing and searching content on ThinkCycle is useful. (rate 1-5)
11. How often do you view content online? (several times a day, once a day, once a week, every month, rarely)
12. What sort of content do you view most frequently? (open-ended)
13. I like reviewing and commenting on content posted by others. (rate 1-5)
14. I find comments on my content posted by others useful. (rate 1-5)
15. You posted XXX Comments & XXX Cross-Links? What do you think prevents you from posting more comments and cross-links regularly?

Posting Content

16. I find that posting ongoing resources, links and concepts for my project on ThinkCycle is useful. (rate 1-5)
17. How often do you post content online? (several times a day, once a day, once a week, every month, rarely)
18. What sort of content do you post most frequently? (open-ended)
19. You posted XXX notes? What do you think prevents you from posting your content on ThinkCycle regularly? (open-ended)
20. You are subscribed to XXX forums and you posted XXX messages? What do you think prevents you from using the discussion forums to post messages regularly?

Concluding Question

21. Do you think using ThinkCycle contributed towards helping you on your design project? (rate 1-5). If so, please state how OR if not, please describe why?

MIT COUHES APPLICTION No. 2915 Participant Code:______

Understanding the Role of Online Tools and Social Incentives Towards Collaborative Design & Learning in Studio Courses

Consent for Participation in Study and Use of Questionnaire and Audio-taped Information

Principal Investigator: Nitin Sawhney, {nitin@media.mit.edu}
MIT Media Laboratory, May-June 2002

This study is being conducted to assess the nature of collaborative design and learning outcomes from individual and team projects in experimental design studios and the use of an online collaboration platform, ThinkCycle. The study solicits voluntary participation in an online questionnaire, optional follow-up interviews and an optional focus group discussion.

I fully understand that my participation in the study is voluntary and that I am free to withdraw my consent and discontinue participation at any time without prejudice to myself. The procedures and purposes of the study have been explained to me and the investigator has offered to answer any inquiries concerning them. I understand that I may voluntarily answer questions in the online questionnaire and that I have no obligation to answer every question. I may also separately agree to be interviewed as a follow-up to this questionnaire, if needed in the future. My identity and all personal information expressed by me will be kept anonymous in any reporting by the researchers. My participation or non-participation in this study will in no way affect grades assigned to me on any courses I am enrolled in at my university. For my participation in this study I will receive a free T-shirt, even if I choose to withdraw from the study early.

If I am asked for a follow-up interview, I understand that my interview will be audio taped if I give permission to the investigators. However, I can still participate in the study if I choose not to be audio taped. The audiotapes will only be heard by the investigators for subsequent transcription and analysis, unless I specify otherwise. All audiotapes will be stored in a locked cabinet, accessible only to the investigators. In the unlikely event that it is impossible to provide such secure storage space, the audiotapes will be destroyed.

In the unlikely event of physical injury resulting from participation in this research, I understand that medical treatment will be available from the M.I.T. Medical Department, including first aid emergency treatment and follow-up care as needed, and that my insurance carrier may be billed for the cost of such treatment. However, no compensation can be provided for medical care apart from the foregoing. I further understand that making such medical treatment available; or providing it does not imply that such injury is the Investigator's fault. I also understand that by my participation in this study I am not waiving any of my legal rights. For further information contact the Institute's Insurance and Legal Affairs Office at 253-2882.

I understand that I may also contact the Chairman of the Committee on the Use of Humans as Experimental Subjects, M.I.T. 253-6787, if I feel I have been treated unfairly as a subject.

I agree to be interviewed after the questionnaire if needed: Yes____ No_____

I agree to be audio taped in this follow-up interview: Yes____ No_____

I agree to let the investigators contact me in the future: Yes____ No_____

Address____ Phone________________

Name____

Signature____ Date_________________

Principle Investigator__________________________________ Date_________________