Contribution to HCIC-2008: *"Education in HCI; HCI in Education"*

Transdisciplinary Education and Collaboration

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Abstract. We explore transformative theoretically-based research agendas for education in IT (specifically in HCI and Informatics) from a lifelong learning perspective by instantiating and assessing the following assumption: *"If the world of working and living relies on collaboration, creativity, definition and framing of problems and if it requires dealing with uncertainty, change, and intelligence that is distributed across cultures, disciplines, and tools—then education should foster transdisciplinary competencies that prepare students for having meaningful and productive lives in such a world."*

Our theoretical framework will be assessed with the experience gained at analyzing research and innovative educational approaches at the Center for LifeLong Learning & Design (L3D), University of Colorado, Boulder and at the Department of Informatics, University of California, Irvine.

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HCI: Beyond User Interfaces

The field of human-computer interaction has many facets (see Table 1) and its role in design and education can be analyzed from a variety of different perspective (e.g.: [Carroll, 1993; Lewis, 1990; Newell & Card, 1985]).

Table 1: Time Frames in HCI (From Newell, A. & Card, S. K. (1985)

Time		Action	Memory	Theory
(sec)	(common units)			
10^9	(decades)	Technology	Culture	Social and Organizational
10^8	(years)	System	Development	
10^7	(months)	Design	Education	
10^6	(weeks)	Task	Education	
10^5	(days)	Task	Skill	Bounded Rationality
10^4	(hours)	Task	Skill	
10^3	(ten mins)	Task	LTM	
10^2	(minutes)	Task	LTM	
10	(ten secs)	Unit task	LTM	Psychological
1	(secs)	Operator	STM	
10^{-1}	(tenths)	Cycle time	Buffers	
10^{-2}	(centisecs)	Signal	Integration	Neural And Biochemical
10^{-3}	(millisecs)	Pulse	Summation	

Our paper is focused on research on exploring challenges and issues from the upper two bands in the table.

Transdisciplinary Education and Collaboration: A Necessity, not a Luxury

Education in IT is experiencing a period of profound transformation. Phenomena such as *globalization* [Friedman, 2005], increasing trends to *outsource high-level cognitive tasks* [Aspray et al., 2006], and the need to participate effectively in addressing *complex world problems* [Brown & Duguid, 2000b] are changing graduate populations and their goals. Requirements increase for students to enter work environments requiring collaboration with experts from [Lewis, 1990]multiple fields, pursue several career paths addressing different problems, and to interact and work with people of diverse backgrounds including those from outside academe. Such changes create new educational demands [Rhoten, 2005]: students need to be educated for a diverse, technical, problem-oriented world that does not yet exist, which makes it imperative that they become self-directed, lifelong learners who can thrive and participate in collaborative environments with ever-changing disciplinary boundaries.

In response to such challenges, transdisciplinary education and collaboration [Derry & Fischer, 2007] is essential for addressing complex and pressing social and scientific problems of our time. Such problems must be addressed by organizations, not individuals; creative solutions emerge within socio-technical environments [Mumford, 1987; Mumford, 2000] in which there is interaction among people and artifacts (e.g., tools, technologies, designs, represented ideas) that embody knowledge from various constituent communities [National-Research-Council, 2003].

Developing Transdisciplinary Competencies

Transdisciplinary competencies refer to knowledge and skills required to identify, frame and address important scientific and practical problems that cut across disciplinary boundaries. Such problems are complex and ill-defined [Simon, 1996] requiring (a) integration of problem framing and problem solving, (b) communication and collaboration among people from different disciplines and educational levels, and (c) intelligent use of technologies and resources that support collective knowledge construction and extend human problem-solving capability.

In preparing students to live and work in the "knowledge age", one cannot predict or learn in graduate school what one may need to know during a lifetime of work [Drucker, 1994]. Coverage is impossible and obsolescence is guaranteed. Rather than trying to broadly cover too much territory, graduate programs could do a better job of empowering all students to learn on demand, exploiting the powers of collaboration and new media as tools for lifelong learning [Fischer, 2000]. Our viewpoint is inspired by Campbell's [1969] fish-scale model, a call for academic organizations that aim for *"collective comprehensiveness through overlapping patterns of unique narrowness. . . . collective achievement made possible by the overlap of narrow specialties"* [Campbell, 2005].

Dimensions of an Emerging Conceptual Framework

We are exploring numerous themes in our efforts to understand and support transdisciplinary education and collaboration. These concepts are derived from fields concerned with collaborative learning in technology-rich environments, including The Learning Sciences, Human-Computer Interaction (HCI), and Computer Support for Collaborative Learning (CSCL)), and they have proved useful to us as tools for thinking about our own research and teaching. Some of our themes are:

- *models of community* [Fischer, 2001], and how shared knowledge and common ground is created to support mutual learning and collaborative problem-solving;
- *distributed intelligence* [Hollan et al., 2001; Salomon, 1993], the idea that intelligence is not located in a single mind but is distributed among people and tools that work together and emerges in the process of problem solving;
- *reflection*, cognitive skills that help individuals and communities intelligently monitor, assess, and adapt their work through such processes as "reflection-in-action" and "reflection-on-action"[Schön, 1983; Schön, 1987].
- *boundary objects* [Bowker & Star, 2000; Star, 1989] entities, such as products, standards or ideas, that serve as communicative interfaces between members of different communities and may help or hinder collaboration;
- *lifelong learning* [Gardner, 1991], representing a fundamental reconceptualization in which education becomes an integral part of working and living rather than taking place primarily in schools;
- *socio-technical design* [Mumford, 1987; Mumford, 2000], the evolutionary creation of effective learning and problem-solving environments made possible with new media and having interacting social and technical components; and
- *exploiting knowledge sources from the long tail* [Anderson, 2006] to engage learner in self-directed learning activities which they feel passionate about.

Research and Innovative Educational Approaches at the Center for LifeLong Learning & Design (L3D), University of Colorado, Boulder

A significant weakness of current educational systems is that they do not deliberately educate for lifelong learning. Rather, current systems require that at a certain point in their development, learners in all walks of life leave school in which they were mostly consumers of educational material and throw a *"big switch"* to become socially competent, responsible, self-directed learners who successfully use tools and technologies to enrich their personal and working lives and who collaborate with one another to solve local and global problems[Illich, 1971]. Yet little of their previous educational experiences have prepared them to do any of this.

Graduate schools could help enrich the cultures of work and learning [Gardner, 1991] and the personal lives of learners by cultivating mindsets and skills for lifelong learning [Fischer, 2000]. Students must be prepared, not only to excel in traditional academic settings, but to contribute knowledge and effort to a world increasingly beset with change, uncertainty and pressing transdisciplinary problems and that will require new forms of scholarship, publication, communication and participation.

There is no media-independent communication or interaction: tools, materials, and social arrangements always mediate activity. The processes of thinking, learning, working, and collaborating are all functions of our media [Bruner, 1996]. Cognition is shared not only among minds, but among minds and the structured media within which minds interact. As we enter a world of *"pervasive computing, with always-on Internet access, reliable quality of service networks, and sufficient levels of technological fluency"* [Pea, 2004], we must address how socio-technical design will shape 21st century education.

Many current educational uses of technology in graduate schools are restricted to what can be thought of as *"gift wrapping"* [Fischer, 2000]: that is, technology is used as an add-on to traditional practices rather than as a catalyst for fundamentally rethinking what education and learning should and could be [Papert, 1995]. But shortcomings of traditional practices—such as lecturing, fixed curriculum, memorization, and decontextualized learning—are not overcome by introducing technology, whether that technology takes the form of intelligent tutoring, multimedia presentations, or distance learning.

Undergraduate Research Apprenticeship Program

The Center for LifeLong Learning and Design (L3D) established an Undergraduate Research and Apprenticeship Program (URAP) in 1998 as an effort by to provide a means for engaging undergraduate students in a real research environment and to provide every interested and motivated the same experiences and opportunities as PhD students have: each apprentice will have a personal mentor and will work on on-going projects.

The underlying philosophies of the URAP are based on the fundamental objectives of the Discovery Learning Initiative, a major initiative at the College of Engineering at CU Boulder (to support this initiative a new building was constructed and opened in 2003).

Specifically, students are engaged in teams and projects that have a *vertically* and *horizontally* integrated structure. Project teams are interdisciplinary by nature and include undergraduate apprentices, Ph.D. students, post-docs, research scientists, faculty, and industry partners from various fields. L3D emphasizes the importance of learning-by-doing. Our model emphasizes a long-term working relationship in which apprentices receive close guidance at first, but over time are expected to engage in more self-directed research as well as serve as mentors for younger apprentices.

Courses-as-Seeds

Courses-as-seeds [dePaula et al., 2001] is an educational model that explores meta-design and social creativity in the context of fundamentally changing the nature of courses taught in universities. Its goal is to create a culture of informed participation [Fischer & Ostwald, 2005] that is situated in the context of university courses transcending the temporal boundaries of semester-based classes for examples see: http://l3d.cs.colorado.edu/~gerhard/courses. Traditionally, the content of a course is defined by the resources provided by instructors (such as lectures, readings, and assignments). By involving students as active contributors, courses do not have to rely only on the intellectual capital provided by the instructors. Courses are conceptualized based on the *Seeding, Evolutionary Growth, and Reseeding* model [Fischer et al., 2001], in which the instructor provides the initial seed rather than a finished product [Rogoff et al., 1998].

Communities of Practice and Communities of Interest

Communities of Practice (CoPs) [Wenger, 1998] consist of practitioners who work as a community in a certain domain undertaking similar work. For example, copier repair personnel who work primarily in the field but meet regularly to share "war stories" about how to solve the problems they encountered in their work make up a CoP [Orr, 1996]. Learning within a CoP takes the form of *legitimate peripheral participation* (LPP) [Lave & Wenger, 1991], which is a type of apprenticeship model in which newcomers enter the community from the periphery and move toward the center as they become more and more knowledgeable (depicted in Figure 1).

Sustained engagement and collaboration lead to boundaries that are based on shared histories of learning and that create discontinuities between participants and nonparticipants. Highly developed knowledge systems (including conceptual frameworks, technical systems, and human organizations) are biased toward efficient communication *within* the community at the expense of acting as barriers to communication with outsiders: boundaries that are empowering to the insider are often barriers to outsiders and newcomers to the group.

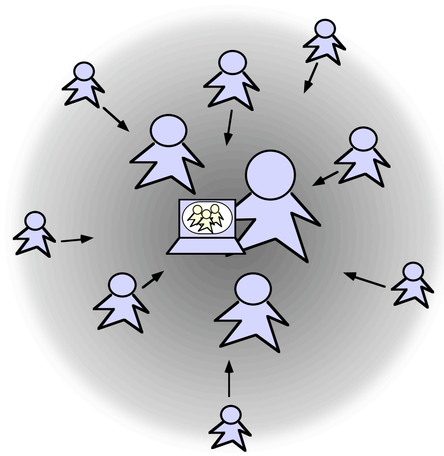

Figure 1. Learning in CoPs

At the center are knowledgeable members and knowledge systems. Members enter the community from the periphery and move toward the center over time through participating in the community.

A community of practice has many possible paths and many roles (identities) within it (e.g., leader, scribe, power-user, visionary, and so forth) [Ye & Kishida, 2003]. Over time, most members move toward the center, and their knowledge becomes part of the foundation of the community's shared background.

Communities of Interest (CoIs) bring together stakeholders from different CoPs and are defined by their collective concern with the resolution of a particular problem. CoIs can be thought of as "communities of communities" [Brown & Duguid, 1991] or a community of representatives of communities. Examples of CoIs are: (1) a team interested in software development that includes software designers, users, marketing specialists, psychologists, and programmers, or (2) a group of citizens and experts interested in urban planning, especially with regard to implementing new transportation systems.

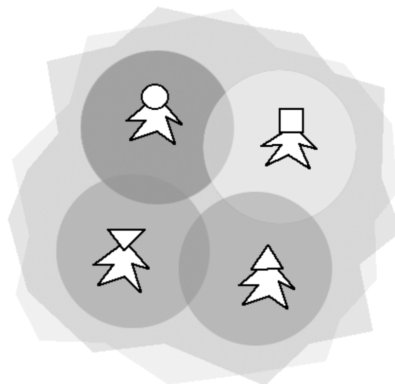

Figure 2: CoIs — Bringing Different CoPs Together

CoIs bring together stakeholders from different CoPs (represented by the different colored circles). The ragged edge of the bounding shape depicts that the boundaries of the problem and the community are not well established, particularly at the beginning of a project.

Stakeholders within CoIs are considered as *informed participants* [Brown et al., 1994] who are neither experts nor novices, but rather both: they are experts when they communicate their knowledge to others, and they are novices when they learn from others who are experts in areas outside their own knowledge.

As a model for working and learning in CoIs, *informed participation* [Fischer & Ostwald, 2002] is based on the claim that for many (design) problems, the knowledge to understand, frame, and solve these problems does not already exist, but must be collaboratively constructed and evolved during the problem-solving process. Informed participation requires information, but mere access to information is not enough. The participants must go beyond the information that exists to solve their problems. For informed participation, the primary role of media is not to deliver predigested information to individuals, but to provide the opportunity and resources for social debate and discussion. In this sense, improving access to existing information (often seen as the major advance of new media) is a limiting aspiration. A more profound challenge is to allow stakeholders to incrementally acquire ownership in problems and contribute actively to their solutions [Florida, 2002].

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

The fundamental barrier facing CoIs is that knowledge distribution is based on an *asymmetry of ignorance (or knowledge)* [Rittel, 1984], in which each stakeholder possesses some, but not all, relevant knowledge, and the knowledge of one participant complements the ignorance of another. This barrier must be overcome by building a shared understanding of the task at hand, which often does not exist at the beginning, but is evolved incrementally and collaboratively and emerges in people's minds and in external artifacts. Members of CoIs must learn to communicate with and learn from others [Engeström, 2001] who have different perspectives and perhaps a different vocabulary for describing their ideas. In other words, this symmetry of ignorance must be exploited.

Comparing CoPs and CoIs. Learning through informed participation within CoIs is more complex and multifaceted than *legitimate peripheral participation* [Lave & Wenger, 1991] in CoPs, which assume a single knowledge system. Learning in CoPs can be characterized as "learning when the answer is known", whereas learning in CoIs is often a consequence of the fact that the answer is not known (e.g., to a complex, unique design problem). CoIs have multiple centers of knowledge, with each member considered to be knowledgeable in a particular aspect of the problem and perhaps not so knowledgeable in others. In informed participation, the roles of "expert" or "novice" shift from person to person, depending on the current focus of attention.

Error! Reference source not found. characterizes and differentiates CoPs and CoIs along a number of dimensions. The point of comparing and contrasting CoPs and CoIs is not to pigeonhole groups into either category, but rather to identify patterns of practice and helpful technologies. People can participate in more than one community, or one community can exhibit attributes of both a CoI and a CoP. Our *Center for LifeLong Learning and Design (L^3D)* is an example: It has many characteristics of a CoP (having developed its own stories, terminology, and artifacts), but by actively engaging with people from outside our community (e.g., other colleges on campus, people from industry, international visitors, and so forth), it also has many characteristics of a CoI. Design communities do not have to be strictly either CoPs or CoIs, but they can integrate aspects of both forms of communities. The community type may shift over time, according to events outside the community, the objectives of its members, and the structure of the membership.

Table 2: Differentiating CoPs and CoIs

Dimensions	*CoPs*	*CoIs*
Nature of problems	Different tasks in the same domain	Common task across multiple domains
Knowledge development	Refinement of one knowledge system; new ideas coming from within the practice	Synthesis and mutual learning through the integration of multiple knowledge systems
Major objectives	Codified knowledge, domain coverage	Shared understanding, making all voices heard
Weaknesses	Group-think	Lack of a shared understanding
Strengths	Shared ontologies	Social creativity; diversity; making all voices heard
People	Beginners and experts; apprentices and masters	Stakeholders (owners of problems) from different domains
Learning	Legitimate peripheral participation	Informed participation

Both forms of design communities exhibit barriers and biases. *CoPs* are biased toward communicating with the same people and taking advantage of a shared background. The existence of an accepted, well-established center (of expertise) and a clear path of learning toward this center allows the differentiation of members into novices, intermediates, and experts (see Figure 1). It makes these attributes viable concepts associated with people and provides the foundation for legitimate peripheral participation as a workable learning strategy. The barriers imposed by CoPs are that *group-think* can suppress exposure to, and acceptance of, outside ideas; the more someone is at home in a CoP, the more that person forgets the strange and contingent nature of its categories from the outside.

A bias of *CoIs* is their potential for *creativity* because different backgrounds and different perspectives can lead to new insights [Bennis & Biederman, 1997; Campbell, 1969]. CoIs have great potential to be more innovative and more transforming than a single CoP if they can exploit the *asymmetry of ignorance* [Rittel, 1984] as a source of collective creativity. A fundamental barrier for CoIs might be that the participants failed to create common ground and shared understanding. This barrier is particularly challenging because CoIs often are more temporary than CoPs: They come together in the context of a specific project and dissolve after the project has ended.

CoPs are the focus of disciplines such as CSCW: They provide support for work cultures with a shared practice [Wenger, 1998]. The lack of a shared practice in CoIs requires them to draw together diverse cultural perspectives. Computer-mediated knowledge communication in CoPs is different from that in CoIs. CoIs pose a number of new challenges, but the payoff is promising because they can support pluralistic societies that can cope with complexity, contradictions, and a willingness to allow for differences in opinions.

Meta-Design: Design for Designers

Education in HCI should contribute to an understanding and the exploitation of opportunities based on the fundamental transformational shift from an *industrialized information economy* (specialized in producing finished goods to be consumed passively) to a *networked information economy* (in which all people are provided with the means to participate actively in addressing personally meaningful problems) [Benkler, 2006].

Meta-design focused on "design for designers" will *expand boundaries and redistribute control in design*. Our educational efforts are based on the following prescriptive objectives and empirical observations:

- *"The experience of having participated in a problem makes a difference to those who are affected by the solution. People are more likely to like a solution if they have been involved in its generation; even though it might not make sense otherwise"* [Rittel, 1984].
- *"I believe passionately in the idea that people should design buildings for themselves. In other words, not only that they should be involved in the buildings that are for them but that they should actually help design them"* [Alexander, 1984].
- *"We have only scratched the surface of what would be possible if end users could freely program their own applications. As has been shown time and again, no matter how much designers and programmers try to anticipate and provide for what users will need, the effort always falls short because it is impossible to know in advance what may be needed. End users should have the ability to create customizations, extensions, and applications"* [Nardi, 1993].
- *"The hacker culture and its successes pose by example some fundamental questions about human motivation, the organization of work, the future of professionalism, and the shape of the firm"* [Raymond & Young, 2001].
- *"Users that innovate can develop exactly what they want, rather than relying on manufacturers to act as their (often very imperfect) agents"* [von Hippel, 2005].
- *"In the digital world, many of the distinctions between designers and users are becoming blurred. We are all, to some extent, designers now"* [Brown & Duguid, 2000a].
- *"The networked environment makes possible a new modality of organizing production: radically decentralized, collaborative, and nonproprietary"* [Benkler, 2006].
- *"The opportunity to generate vibrant customer ecosystems where users help advance, implement, and even market new product features represents a largely untapped frontier for farsighted companies to exploit"* [Tapscott & Williams, 2006].

The technological foundations to make these objectives a reality are provided by a powerful infrastructure for collaborative efforts (the Internet allows people to share their efforts) and by the increased digital fluency [National-Research-Council, 1999] of the population in general, which will make owners of problems independent of "high-tech scribes' in personally meaningful tasks [Fischer, 2002]. Emerging success models, such as open source software and Wikipedia, have provided evidence of the great potential of socio-technical environments in which users can be active contributors.

Research and Innovative Educational Approaches at the Department of Informatics, University of California, Irvine

HCI Education subsumed by Informatics?

The course of study for bachelor students in the Informatics degree program at UCI includes a course specifically with human-computer interaction in the title. That course focuses on issues of interactive computer user interfaces [Shneiderman, Plaisant, 2004; Preece et al. 1994]. However, the students are taught in this and many other courses that the factors that affect and are affected by software systems go beyond individuals to groups, organizations, and society. In fact, the term *HCI* has the overloaded meaning now of any human aspect related to computing.

Phrasing from our catalog generally characterizes the courses in our Informatics program as follows: "topics that address the relationship between information technology design and use in social and organizational settings" (from the UCI catalog - http://www.editor.uci.edu/07-08/ics/ics.4.htm#gen0). Thus, however HCI may have been interpreted by researchers and practitioners who initiated the first CHI conference, it is broadly interpreted in our curriculum today at UCI. The broad interpretation parallels the growth in the field as researchers and practitioners reflected on and reacted to many failures as well as successes of interactive computing. Students at least are taught to look beyond the immediate requirements of technology, toward elements motivated by human stakeholders.

In parallel with the broadening of the concepts attributed to the field of HCI, a theme of *informatics* or information studies has evolved. Consider this extended quote from an interview with John King about the program at UCI. The interview is part of an on-line memorial to Rob Kling:

> *I understand that you were part of the CORPS (Computers, Organizations, Policy and Society) faculty with Dr. Kling at the University of California, Irvine. Can you describe how this group came about and its contributions?*
>
> *I was hired onto the faculty of Information and Computer Science at UCI in 1980 by the then chair of the program, Julian Feldman. Julian was one of the early artificial intelligence researchers, a student of Herbert Simon. He had recruited Rob to UCI. Julian, Rob and I formed a kind of rump group within ICS that was known simply as "Area 5." It consisted of the small but growing software group and what we vaguely called "applications." Rob wanted to create a concentrated focus on social aspects of computing, and Julian was amenable. My own interests were more along managerial lines, so I proposed Social and Managerial Analysis of Computing – SMAC. Rob wasn't quite ready for that acronym. We went back and forth and finally settled on CORPS. It fit the bill, readily containing the interests of both Rob and me. Mark Ackerman soon thereafter joined us from MIT, and then Jonathan Grudin joined the group. CORPS began to weaken as an organizational entity when Rob left for Indiana in 1996; in relatively short order, Jonathan left for Microsoft Research, I left for Michigan, and Mark left for MIT (and eventually Michigan). CORPS was pretty much finished by 2001, but by that time we had established a strong partnership with the Software group (history coming full circle!) and CORPS and Software became the nexus of the Informatics Department within ICS at UCI.*
>
> [http://rkcsi.indiana.edu/article.php/interviews-with-colleagues-and-friends/104]

Is *informatics* the *new HCI,* as one of the questions in this year's HCIC call asks? At Irvine, and many other universities, the human dimensions to computing are given increasing weight. A collection of schools, the vast majority with *informatics* and *information* in their names, form a caucus of *iSchools.* Consider the collective definition on their Web home page:

> *The iSchools are interested in the relationship between information, technology, and people. This is characterized by a commitment to learning and understanding the role of information in human endeavors. The iSchools take it as given that expertise in all forms of information is required for progress in science, business, education, and culture. This expertise must include understanding of the uses and users of information, as well as information technologies and their applications.*
>
> [http://www.ischools.org/oc/field.html]

A broad interpretation of HCI is well motivated by founders such as Herbert Simon who calls for a broad "curriculum for social design" [Simon, 1996]. Schön [Schön, 1983; Schön, 1987], calls on educators to challenge the limits of technical rationality. Derry and Fischer [Derry & Fischer, 2007] have put forward the notion of transdisciplinary education.

Lessons from Suchman's work instantiate further the limits of technical rationality [Suchman, 1987]. Newell and Card's table (reproduced in the first section) implies the need to incorporate the social and organizational in addition to psychological and bounded rationality levels of phenomena [Newell & Card, 1985]. Greenbaum & Kyng [Greenbaum & Kyng, 1991] and the larger tradition of socio-technical design [Mumford, 2000; Scacchi, 2004; Trist, 1981] also outline a broader range of concepts needed for understanding and creating information systems. Many of these ideas have been woven into an educational framework introduced in the first part of this paper, a framework called *transdisciplinary education*. Two sets of experiences will be used:

- Experiences at the L3D center in Boulder [Fischer et al., 2007] and
- the instantiation of a new program in software engineering that particularly emphasizes HCI education at the University of California, Irvine, Department of Informatics.

For the remainder of this part of the paper we will focus on applying our framework of *transdisciplinary education and collaboration* to the Informatics degree program at UCI. We are especially anxious to do this analysis. First, the program is new and we are generally interested in critical feedback. Second, new or otherwise, the faculty continually seek to make the program offerings the best possible. Third, we have a general belief that although our Informatics program and the framework for transdisciplinary education were conceived independently, the ideas and motivations rooted in the work above make it similar. The application of the framework to evaluate our program will demonstrate the degree to which that supposition holds.

An Overview of the BS in Informatics

The main principles of the Informatics program at UC Irvine are based on the following insights and assumptions:

- *technological concepts are insufficient* the educate future IT workers; courses on the *human dimension* –HCI, social impacts, ethnography, CSCW, and management – are an essential complement;
- *relevance of the educational experience* [Schön, 1983] for students requires that courses *integrate* theory as closely as possible with the context in which it is typically used, with the exception that the capstone project class exercises all the material;
- *generality (breath) must be balanced against specialty (depth)* thereby setting up an ongoing act of balancing one discipline with others in an interdisciplinary degree.

Table 3 shows the four-year program of the BS in Informatics. The names of the courses are very suggestive of their themes, but the relevant pages of the catalog of classes are reproduced in the Appendix. Irvine is on a quarter system. Traditionally, the academic year focused on the three quarters that spanned the fall, winter, and spring. There is a move to treat the summer quarter as a regular part of the academic year, but the UC system is still coming to terms with the implications of such a move. Thus, as in many universities, the summer quarter is devoted to classes that either give students a head-start in some area, lightening their workload for the upcoming year, or to give some students the opportunity to compensate for a missed class or re-take a class they performed poorly in.

Table 3: An Outline of the UCI BS in Informatics (reproduced from [van der Hoek, et al. 2006])

	Fall	*Winter*	*Spring*
First	Informatics Core	Informatics Core	Informatics Core
			Informatics Research Topics Seminar
	(o) Critical Reasoning	(o) Discrete Mathematics	(cs) Fundamental Data Structures
	(b) Writing	(b) Writing	(b) Writing
Second	(o) Statistics	Human-Computer Interaction	Project in Human-Computer Interaction and User Interfaces
	(cs) Concepts Programming Languages I	Concepts Programming Languages II	Software Design I
	Software Methods and Tools	Requirements Analysis & Engineering	Software Specification and Quality Engineering
	(b) Breadth	(b) Breadth	(b) Breadth
Third	Social Analysis of Computerization	Organizational Information Systems	Project Social and Organizational Impacts of Computing
	Software Design II	Software Architecture, Distributed Systems, and Interoperability	(cs) File and Database Management
	(b) Breadth	(b) Breadth	(b) Breadth
	(b) Breadth / Elective	(b) Breadth / Elective	(b) Breadth / Elective
Fourth	Senior Design Project	Senior Design Project	Senior Design Project
	(cs) Project in Database Management	(cs) Information Retrieval	Information Visualization
	Project Management	CSCW	(b) Breadth/ Elective
	(b) Breadth / Elective	(b) Breadth / Elective	(b) Breadth / Elective

The focus of the first year is on a three quarter sequence of core concepts. The core sequence instantiates all three assumptions of our program: the complement of technology and human dimensions, integration of theory with context, and the balance of generality and specificity. Programming languages, operating systems, data structures, software engineering, design, HCI, and social and organizational impacts of technology are all touched on in this core curriculum. The same instructor generally teaches all three courses in the core sequence. Thus, the instructor can more easily emphasize concepts across the courses, making forwards and backwards references, making clearer to the students how concepts and contexts are integrated more realistically.

In the subsequent years of the program, the great degree of breath in the core sequence is balanced with depth by specific courses that explore themes in one, two, and even three course sequences. Again, when possible, continuity is maintained among the instructors to facilitate the references to related theory and practice to build up relevance in the students' minds. In particular, in year two, two themes come into play. Software engineering is broadly one theme, instantiated by course sequences in programming languages and software design. The second theme is human-computer interaction, specifically theoretical background followed by a project course focusing on evaluation. Although, in year two, the human dimension is somewhat the lesser of the two themes, in year three, human-centered issues play a more prominent role, with two courses on social and organizational impacts, followed by a project course. In year three, software engineering is somewhat the lesser of the two themes.

The final year of the program is specifically designed for the integration of all of the concepts and practices of the first three years. Specifically, a capstone project that runs as a three quarter sequence integrations all activities of a systems development, including requirements gathering and evaluation from an HCI, organizational, and social impact perspective.

Analysis of the BS in Informatics in terms of Transdisciplinary Education

As discussed previously, we now proceed to analyze the program with respect to Derry and Fischer's framework for *transdisciplinary education* [Derry & Fischer, 2007]. Specifically, the framework describes the following components: Community Competencies, Competencies for Self-directed Lifelong Learning, Socio-Technical Knowledge, 21st Century Teaching, and Engaged Citizenship. The reader might think of this analysis as a *heuristic evaluation* with Derry and Fischer's framework providing the checklist of key attributes. Other presentations and critical commentaries on our program may be found elsewhere [van der Hoek et al., 2005a; 2005b; 2006].

Community Competencies

Derry and Fischer describe a variety of techniques by which students demonstrate competency in community-wide reflection, with the integration of different perspectives from many disciplines. In this vein, the program in Informatics succeeds to a large degree but still lacks one element. Specifically, there is success in 1) integrating the knowledge of many previously separated disciplines 2) *in situ* reviews by faculty and students, and 3) individual reflection. Where the program is lacking is that 4) community reflection is more implicit than explicit. Let's consider each of these components and the potential for improvement.

First, the summary of the program in the previous section made clear the many disciplines involved in our program and that the program generally integrates through out the courses of the four years: software engineering, organizational studies, social implications, and industry sponsored projects. Moreover, the background of our faculty in computer science, psychology, anthropology, and media arts, indicate additionally the different disciplines the program integrates.

Second, the students have many opportunities for reflection as a community. The best example of *in situ* review is a quarterly project jury wherein student teams present their senior project update to the Informatics faculty as a whole – not just the faculty involved in the course. This presentation is followed by an interactive time of demonstrations and discussion. Student teams develop their own questionnaire for faculty to comment more formally on the project. In fact all of the many project classes, years 2-4 of the curriculum, provide status reports and demonstrations in front of peers and faculty members.

Third, individual reflection takes place in three major occasions. First, there are on-line student course evaluations. The students perform these for each course during the last few weeks of each quarter. Second, a social group for the students in the program, run by students, allows for informal communication and reflection. Third, aside from the course evaluations, there are occasional, in-depth surveys of the program. The above occasions for reflection are in addition to opportunities for individual reflection that are normal parts of courses. Those would include, e.g., Q&A sessions in class and in discussion sections, quizzes, exams, and homeworks.

Above, we wrote that a fourth aspect of community competency, community reflection, "is more implicit than explicit." Specifically, community reflection is not taught as a specific theory for the undergraduates. However, it is practiced as a skill as in the activities described in the previous paragraph. To a degree, reflection is part of the software lifecycle instruction. Specifically, part of the theory of software process is to reflect on and refine process. However, this is not a transdisciplinary activity, but a software specific concept at this point.

In sum, community competences are a large part of the program in Informatics. However, there is room for improvement. Namely, community reflection could be taught explicitly in theory as a transdisciplinary activity as opposed to just practiced as it stands in the program today.

Competencies for Self-directed Lifelong Learning

Once again, we return to Derry and Fischer for the definition of this aspect. Simplifying their description, competencies for self-directed lifelong learning have roughly two components 1) applying knowledge in varied contexts and 2) making appropriate assessments of success. When an individual can become a reflective practitioner, they have skills for lifelong learning.

In order to maximize the possibility of students learning theoretical concepts in a way that allows them later to apply them to varied contexts, the informatics program, as previous described, spreads references to concepts and practice with those same concepts throughout the four years of the program with an attempt to exercise all the multi-disciplinary knowledge in senior capstone project.

The greatest chance to practice self-directed learning however comes in the project classes. Project courses seek explicitly to integrate knowledge from many different classes. In the Informatics program, the Senior Design Project is the most comprehensive in this integration: requirements analysis, analyzing the social and organizational context, developing and documenting appropriate progress markers, testing and evaluation, evaluation may include user interface evaluation, and so forth. In addition, students often need to learn some new area depending on the project with which they are matched.

Matching students to projects involves an external client. That client may be a faculty member or group somewhere on campus, but most often, it's an industrial partner. Industrial partners pay a donation according to a varied scale depending on their size and for-profit or non-profit status (http://www.ics.uci.edu/community/friends/proj125/index.php). One current project is to develop a social networking site for a large company. Students are learning social networking theory on their own while drawing on their courses in organizational and collaborative systems, software design and architecture, and human-computer interaction to name a few.

The challenge of working with a client on a project course and learning what needs to be learned, and learning it, is a perfect example of preparing students for life-long learning.

Socio-Technical Knowledge

In the description of transdisciplinary education, socio-technical knowledge comprises technologies that support social interaction. Examples from [Derry & Fischer, 2007] are "blogs, web portals, games." Indeed, students in the Informatics program are well versed in these technologies. A recent project class in human-computer interaction focused on technologies such as AJAX and Web 2.0.

However, socio-technical knowledge is so much more than knowing just how to develop social oriented software, it involves an appreciation of the human individual, organizational, and even social impacts of the technology [Scacchi]. Basic concepts of individual human-computer interaction are covered in one course through theory and homework practice. Students learn about interactive computing, evaluation of interactive systems, multi-media, visualization, and other innovative interaction techniques. In a larger context, they are practiced the following quarter in a project course. Social impacts and organizational implications of information systems are covered in two quarters with the third quarter practicing the concepts in a project class. Concepts include controversial computing applications such as electronic voting, monitoring and privacy issues, legal implications. In the organization focused class, students learn about organizational theory, how to view organizations as a field site, how to develop a theory, and understand workplace issues. They practice both these quarter courses in carrying out a project in the third quarter.

The program in Informatics provides students with an exceptionally strong background in socio-technical knowledge, exceeding just the development and use of social computing but the fullest understanding of its individual, organizational, and societal impacts.

21st Century Teaching

Bringing reflection as a community activity into teaching is the general concept behind 21st Century Teaching. At UCI, the Teaching, Learning, and Technology Center (http://www.tltc.uci.edu/) supports explicit activities for faculty to reflect upon and improve their teaching skills. The center as part of its mission seeks out new technology such as the latest in ever-changing video conferencing and distance education technologies. It maintains a Web-based system to facilitate teaching activities simplifying the creation of a Web presence for instructors who may not be technically savvy. The technology supports email discussion, grade recording, and much more. Classes put on by the center also help with different aspects of teaching and technology. Individual mentoring of faculty is available along with professionals from the center sitting in on or videotaping instructors.

In the Department of Informatics, faculty members bring teaching concerns to faculty meetings for discussion. Ideas about improving course delivery or dealing with difficult student situations are not uncommon topics of discussion. Every two to three years, a faculty member is reviewed by his or her peers in a merit process. Teaching evaluations and a discussion of the faculty member's teaching are a mandatory part of this process. It is a more formal moment for reflection on teaching skills and techniques.

The University has an annual cycle of catalog revision that begins in the Fall around October with a deadline in early December for catalog changes. The rhythm of this cycle prepares faculty for an annual reflection on the curriculum, including which courses to add, delete, or modify.

In sum, the Department of Informatics and the UCI as a whole trains faculty for reflection on their teaching and curriculum. Technology is a key part of teaching in our environment and new ways of using it are key. The project classes discussed extensively above are key opportunities for mentoring students.

Engaged Citizenship

Our course, Social Analysis of Computerization, is the best example and longest running course that teaches students to be engaged citizens regarding technology and computing. The course trains students to question the value and impact of technology. Surveillance and privacy, electronic voting, implicit age discrimination in computing systems, legal issues, and government policies are some examples included in this course. As mentioned above, these concepts are brought up in other settings for the students to engage as well, especially in the project courses.

Courses with more specific social issues are becoming more common. Recently our department introduced a course on "Green IT." The course examines the impact of technology on the environment: electronic waste, technology life cycles, engineering of the environment are some topics. Another new course examines the social impact of web technology, including social computing.

There are many opportunities for undergraduates to do special independent study courses. A great number of these recently have focused on ubiquitous computing, which is field that integrates social concerns and many aspects of technology.

In sum, the BS in Informatics gives students a great deal of preparation and practice in engaging issues of good citizenship in an informatics age. They are taught not to be *utopians* about technology but realists. Indeed, vision behind the BS in Informatics was in part to train students to be prepared for a society in which understanding of and engagement of information technology was a key to success.

Looking To the Future

Our exercise in applying the framework of transdisciplinary education to the UCI program in Informatics reveals many similarities in ideas and goals. We seek to create reflective professionals who have the capacity for life-long learning and we seek to foster a respect and ability to work with the perspectives of many, formerly separate disciplines. If there was one weakness identified in the Informatics program, it was that community reflection could be taught better as an explicit and general activity. Indeed, in one of the recent town hall meetings, the students noted how useful some of the current reflective exercises are (such as the periodic questionnaires). They find value in the reflection – a sign we are moving in the right direction with our program.

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CU Boulder is an innovative campus to explore new ideas about education and the following units have explored different aspect of transdisciplinary education and collaboration:

- Institute of Cognitive Science (ICS) (http://ics.colorado.edu/);
- Alliance for Technology, Learning and Society (ATLAS) http://www.colorado.edu/ATLAS/;
- Discovery Learning Initiative and Center (DLI/DLC) http://engineering.colorado.edu/DLC/ and
- the Integrated Teaching and Learning Laboratory (ITLL) http://itll.colorado.edu/ITLL/

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The **BS in Informatics Catalog Pages** can be found online in the UCI Catalog at: http://www.editor.uci.edu/07-08/ics/ics.4.htm#gen0.

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