Technology in a Context: Enabling students to collaboratively participate at the interface of computation and social science

Abstract: How do we develop students who can participate critically at the interface of computation and social science? The narrowness of traditional departments, the culture of Computer Science Departments in particular, and a teaching standard that emphasizes high baud rates of information flow are amongst the general reasons why educating students to a more reflective orientation is difficult. This paper explores the use of technology to organize the collaboration within a class so as to produce Computer Science students who learn to develop technology within a critical framework. A case study is presented that shows how technology can be used to produce objects of reflection and analysis for the multi-disciplinary theoretical analysis of online activity.

Introduction

For a number of years the first author has been teaching a suite of courses in a Computer Science Department that try to put computation, and technology in general, in a context. There are several general obstacles to the development of a critical practice within Computer Science:

- The narrowness of traditional disciplinary boundaries and the mechanics of completing requirements for a major make it difficult to attract students to multi-disciplinary courses.

- The culture of Computer Science departments tend to be antithetical to any kind of critical stance towards the analysis, design, engineering, and deployment of technology. In Computer Science, theory is equated to formalization and practice to technique. The context of computation, the actors and their various concerns, the interface of technology, social science, and the humanities, is mostly ignored or trivialized. Students trained in this tradition are not easily coaxed into exploring the interface of technology with disciplines outside the sciences, nor do they as a group appreciate the rigor of non-formal theoretical work.

- The standard model of teaching is to douse students with a fire hose of information. Students learn to organize and retain information despite very high baud rates of information. This approach to education is not conducive to a critical stance. A different pace of action – with opportunities to pause and reflect, be discursive and thoughtful – is required for an educational practice that invites reflection.

There are several general principles for organizing classroom activity that enables an interdisciplinary framework for technology. Draw students from multiple disciplines. Treat the students, the TA's, and the professor as a community of practice. Blend teaching and learning with research and participation. Blur the boundaries between theory and practice. Craft coursework that ties technology to evaluation. Alternate between studying context through the lens of technology and technology through the lens of context. Organize and evaluate class work based on participation.

There is not space in this paper to motivate all of these principles. The key one is using participation as method of education and training (Lave & Wenger, 1991). A practice is required for students to acquire the theory and various modes and methods of analysis that lie at the interface of technology and social science. Changing the kind and level of student participation during the semester enables students to move from peripheral participation via instructor-led lectures and discussion to critical participation. The objects of analysis and reflective study that mediate the interaction within the class are produced by collaborative technology.

An interdisciplinary framework as applied to the development of technology has two key components: theory and methods. A general thesis is that student collaboration, and the use of collaborative technology, is a significant element of any approach to these issues. The role of technology is to bring the interaction among the students, with or without the instructor, closer to the point at which the students actually apply the methods to a technical problem (Roschelle, 1992; Roschelle & Teasley, 1995) within the zone of proximal development (Vygotsky, 1978).

This paper will focus on the use of collaborative groupware technology to explore the interface between technology and social science. The use of technology helps students to practice with alternate disciplinary frameworks, developing multi-disciplinary ways of orienting and methods of operation.

This paper presents a case study of a class at Brandeis University that used collaborative technology as a foundation for course material that puts technology in an interdisciplinary context. The case study reprises the details of a course that taught multi-disciplinary theories of intersubjectivity to computer science undergraduate and graduate students. In this course, technology was used to record the student's own online collaborative activity in a representational form that was reviewable and thereby accessible as an object of analysis and reflection. The use of the collaborative technology gave students first-hand experience with the object of study, supporting student learning for the entire range of research and development activities, both theoretical and practical, from theory, to method, to evaluation.

Collaborative Technology that Supports Learning Theory and Student Reflection

The case study we will discuss is a course taught in Computer Science in Fall 2005, Computational Cognitive Science, which was composed of a mix of graduate (13) and undergraduate (15) students. The material in the Computational Cognitive Science course is conceptually difficult. During the semester the students' level of participation and engagement is changing, gradually moving towards a first-level of mastery. The first part of the semester is spent working through a demanding reading list, especially for the computer science students whose orientation is primarily technical; in Fall 2005 the topic was intersubjectivity (Alterman, *forthcoming*). During the second part of the semester the students practice methods of transcript analysis. The last part of the semester was a workshop where the class collectively worked at reading transcripts as they proceeded with their term projects. The use of collaborative technology to create objects of reflection and analysis is critical to the development of the students' practice.

Readings for the first part of the course came from a mix of disciplines with topics ranging over conversation analysis, planning, common ground, activity theory, distributed cognition, and cultural historic models of cognition. During this part of the course, interaction and representation were two of the major themes of the discussion.

For a traditional cognitive scientist, individual beliefs about the collaborative field of action compose the intersubjective space in which the actors operate. The commonness of the sense that is made by individual actors depends on the degree to which the private understandings of the situation – as it is internally represented – correlate. Or alternately, the commonness depends on the amount of work it takes to align the private understandings of the individuals in order to accomplish some cooperative task.

Other accounts either extend or compete with this framework of analysis. Interactionist accounts locate intersubjectivity in the production and use of representations, not the content itself (Schegloff, 1992; Garfinkel, 1967; Clark, 1996). Distributed cognition extends the set of representations to those that are external, closely examining how a set of representations function within a community of practice (Hutchins, 1995a; Hutchins & Klausen, 1992). A cultural historic account of intersubjectivity closely examines the historical character of the participants' shared activities and the role of mediation (Vygotsky, 1978; Cole & Engeström, 1993; Nardi, 1996). And so on.

Making this kind of interdisciplinary theoretical material relevant to a class of students who are largely computer scientists is not a trivial task. The material is relevant to the technical development of online environments that support collaborative effort within a community. If nothing else, the theoretical material explains why many network-mediated activities or organizations think their virtual community is an impoverished form of collaboration when contrasted to communities that regularly meet face-to-face. But the theoretical material has more relevance than that. The first step towards integrating mediated forms of interaction into emerging or existing communities of practice is to understand the requirements. Only then is one in a position to design and engineer environments that best match the practice given the constraints of the technology. Other value can also be achieved by understanding what cannot be done and why not. It is also a bit of a surprise for computer science students to discover that what occurs online is a significant source of data for navigating a safe route through contentious theoretical waters.

The middle part of the course was more methodologically oriented. There was a general discussion of ethnography. The main focus was to learn some analysis techniques that would force students to read the transcripts at a word-by-word level. Amongst the techniques we looked at were interaction analysis (Suchman & Trigg, 1991), propagation of representational state (Hutchins & Klausen, 1992; Rogers & Ellis, 1994; Perry, 2003), project markers in discourse (Bangerter & Clark, 2003), and referential structure analysis (Feinman & Alterman, 2003).

During the semester, the students used some homegrown groupware technology (CEDAR) to generate replayable transcripts of teams of students collaborating online, same time/ different place, while constructing a Wiki as the product of their efforts. CEDAR supports online collaboration by providing students with a set of "What You See Is What I See" (WYSIWIS) components: a public chat, shared Wiki editor, shared web browser, and a document overview that displays a map of the Wiki structure that the users create and maintain. CEDAR was developed using the THYME and Sage toolkits that were also produced at Brandeis University (Landsman, 2005); these toolkits enable the rapid implementation of a groupware system that produces complete replayable transcripts of online user behavior. CEDAR was constructed by one of the TA's for the class (Johann Larusson), who is doing research on educational technology.

All students were required to participate in data collection exercises using CEDAR. For the first set of exercises, various size teams of students acted as travel agents and were asked to organize a trip for the TA to one or another conference given a limited budget. These exercises helped familiarize students with what it is like to collaborate in a non face-to-face situation. Because the CEDAR technology was still in beta form, these exercises also exposed the students to the joys of working with fragile experimental technology. The data collected was used to teach the transcript reading techniques that were taught in class. The students used segments of transcripts as a basis for a term project proposal.

After the students proposed projects, the class participated in a work session to redesign the tool and refocus the data collection exercise. This part of the use of the technology helped students to develop the scientific practice of experimental design. It also enabled the students to engage in a motivated re-design task. It also helped them to produce data that would benefit their term project. A key feature of this exercise was that the students were forced to switch among alternate tasks and frameworks: the development of their research problem, the design of a collaborative interface, the production of data to study their research task, and the analysis of the content of the online collaboration. The re-designed and re-implemented CEDAR was used to collect additional transcripts during a second set of data collection exercises. During the semester the students voluntarily posted additional tools for transcript analysis.

The last part of the course was run like a workshop with the students continuously working on the analysis of transcripts; the class also continued to read papers. As a term project the students were asked to do an analysis of the data that focused on one or another feature of the joint sensemaking of the online collaborators. The term project synthesized the theoretical and methods portions of the course. At the end of the semester the students filled out a questionnaire to help us assess the value of the CEDAR technology as support for their learning.

CEDAR: The Technology

The CEDAR application is a collaborative platform and an application wrapper around a wiki website. CEDAR provides all the usual features of a MoinMoin wiki (Hermann, 2006), as well as additional collaborative functionality to support synchronous cooperation.

CEDAR runs on any platform that is compatible with the Java Runtime Environment (JRE). The user interface is comprised of five different WYSIWIS components (see Figure 1) where each component supports different aspects of online collaborative activity. The goal of each component is to simplify or resolve issues that can occur during online cooperative work by either supporting user-to-user(s) interaction or user-to-wiki-interaction.

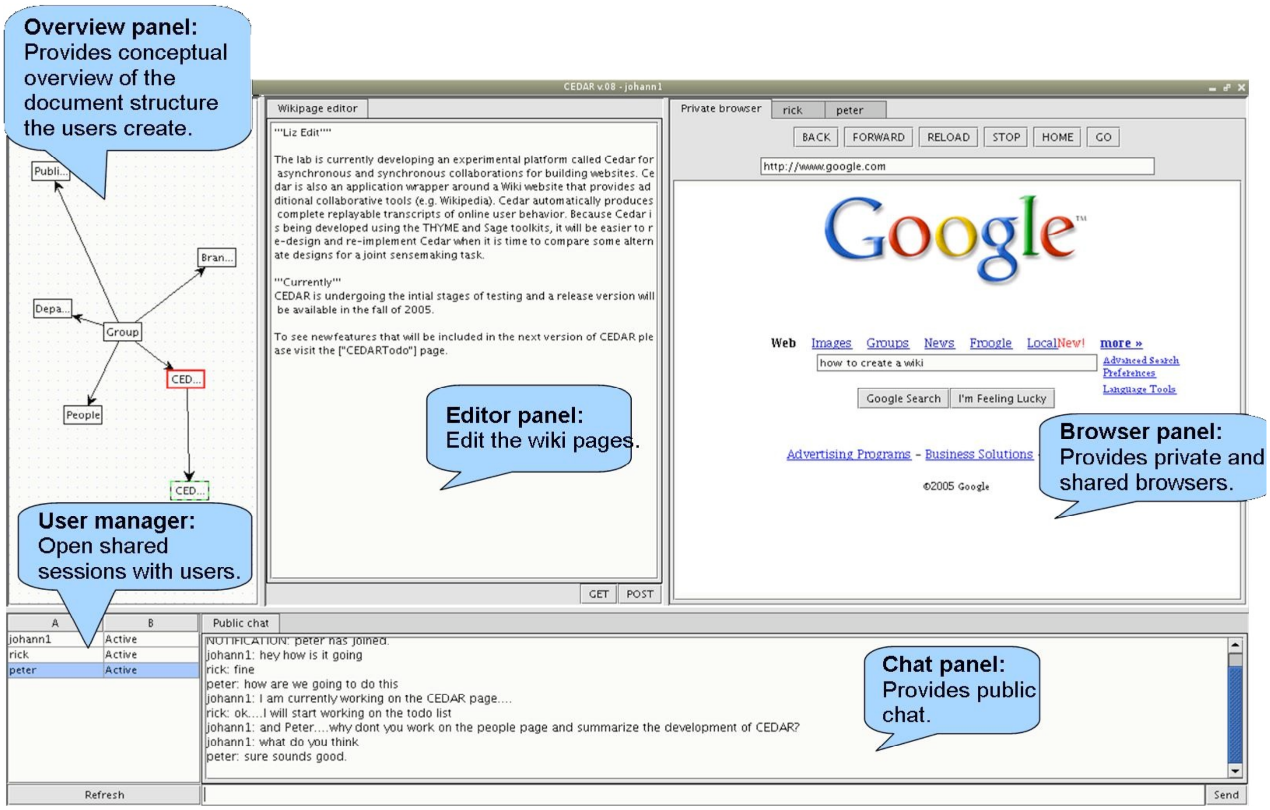

Figure 1: The CEDAR Interface.

The five components are the following:

- UserManager – Lists online users and provides actions that can be selected to interact with remote users, either one or many at once.
- Chat – Provides users with basic instant messaging functionality. Users can communicate via public or private chats that allow either one-to-one or many-to-many private conversations.
- Browser – A basic web browser that users can use to surf the web or the wiki. Users had access to their own browsers. Users could also view, but not operate, each other's browser.
- WikiEditor – Users can edit the wiki pages via this editor. Users could also view the wiki page that another participant is editing as the edits occur. It is possible for two different participants to be editing the same page at the same time. This leads to issues in coordination.
- Overview – Provides a conceptual overview of the wiki document structure that the collaborators create.

CEDAR automatically produces complete replayable transcripts of online user behavior. Transcripts can be reviewed as if the analyst was playing a videotape of all online user behavior. A *complete transcript* of an online practice captures both domain actions and user interface events. It also contains information sufficient to recreate the state of the application at each point in time. (Landsman, 2005). A *playback application* replays a transcript of an online session of system use. The playback application that was used in class enabled the students to: replay the transcript, stop the play of the transcript, vary the speed at which the transcript is replayed, rewind the play of a transcript, automatically stop the replay when certain types of domain actions occur (like a chat), and return to a specific time point in the transcript.

The capability to review online collaborative work enabled the class to closely examine and reflect on their own collaborative experiences. This capability serves a range of theoretical and practical functions.

1. The exercise of collecting transcripts teaches experimental design and methods.
2. The participation of the students in the data collection exercise gives students first hand experiences at online collaboration.
3. The first hand experience of the students as both collectors of data and participants in online collaboration are an object of reflection.
4. The transcripts provide concrete data for exploring and evaluating a theoretical framework.
5. The transcripts are a source of design problems and also a testing ground for design innovation.
6. The transcripts provide concrete data for teaching and practicing various kinds of analysis methods.
7. The collection of transcripts is a shared repository of data for term projects.
8. The transcripts are a basis for classroom discussion.

CEDAR in the Classroom

The First Round of Data Collection and Analysis

CEDAR was initially introduced to the students one month into the semester before any official data collection exercises. This gave the students some hands-on experience with online collaboration, and in preparation for data collection exercises, helped us to identify some last minute fixes to CEDAR.

The class was divided into teams of 2 to 5 students where each team played the role of a travel agent and the task required them to collaboratively construct an itinerary for a graduate student to attend a conference. Through CEDAR they collected information on flights, hotels, and the conference and constructed an itinerary in the form of a wiki page. The teams were required to submit the itinerary to ”their client”. The client critiqued the itinerary, and asked for changes to be made – usually this meant a change in budget that forced the team to rework the itinerary.

Because CEDAR was still in beta stage, these exercises provided an opportunity for some motivated discussion of design for use. The data we collected was used for exercises in class that forced students to apply various kinds of transcript analysis methods. Analysis of the data was also featured on the second exam that assessed their skill at applying the transcript reading techniques they had been taught, and provided a basis for term project proposals.

During lecture, the initial set of data was replayed to apply theoretical concepts to concrete data and teach the students the transcript reading techniques. Students were encouraged to bring their laptops to class so they could break out into smaller groups and practice transcript analysis. The cycle of reading theoretical papers, collecting data of the students collaborating online, and then finding applications of theoretical concepts in the transcripts the students generated is a powerful way to help students ground the theory and see that it is relevant.

The transcripts document how the students sometimes struggle to coordinate activity as they proceed with their cooperative task. Figure 2 shows a small segment of transcript that illustrates the occurrence of a certain kind of *discoordination* within the groups (Engeström, 1992: p. 19). At line 8, Ellen asks for a volunteer. At line 9, Mia volunteers to do the task. But at line 12, Ellen asks again for a volunteer, and at line 13 Mia must repeat her offer. What is the source of the difficulty? The participants are multitasking and textual chat, as a communication channel, is not perfectly sequential. Both of these are factors that explain why the *grounding of commitments* (Clark, 1996) among the participants is faulty on occasion. As a cognitive engineer the repeated occurrence of these kinds of discontinuations signal that the structure of the mediated interaction needs further refinement.

008	Ellen:	someone please look up the dates of the conference
009	Mia:	I'll do that
010	Ralph:	http://iceland.cs.brandeis.edu/cedar/moin.cgi/
011	Sam97:	and then?
012	Ellen:	who is looking up dates of teh conference?
013	Mia:	i am

Figure 2: An example of discoordination during activity.

The literature on hierarchical structure of task dialogues and the relation of talk to action and/or learning has a rich tradition in Cognitive Science. The recent work of Bangerter & Clark (2003) is an example of theory that examines the relation of talk to action. In their model, joint activity is organized into projects and subprojects. Markers in discourse – words like *yes, okay, all right* – tend to be used to either sequence through projects (*yes*) or to open and close subprojects (*okay*, *all right*). In class, the project maker work of Bangerter & Clark was taught as a method of analysis; we also talked about how this analysis method could be used to characterize how closely and at what depth the participants collaborated (Taneva, Alterman, and Hickey, 2005). Using this analysis method, students could "read" transcripts and "see" how the participants used project markers to interactively organize their collaborative work. In the segment of transcript shown in Figure 3, Mia and Ellen use project markers to organize their joint activity to settle on a method for the client to travel from the airport to the hotel. Starting at line 235, Mia introduces a subproject to find a taxi service. At line 237, Mia closes that subproject which is subsequently acknowledge by Ellen in line 239. At line 240, Ellen initiates a "side sequence", starting subproject to coordinate how the group edits the travel wiki page. At lines 241 and 242, the other participants acknowledge that they will also adhere to that convention and thereby close that subproject. The transcript continues with more projects and subprojects being opened and closed. The analysis of transcripts like this help the students to see that learning the project marker method of analysis is not an idyll exercise. The transcripts also provide numerous opportunities for the students to practice this method of analysis in preparation for their exams and term projects.

235	Mia:	ok i'll serch for the taxi again
236	Ellen:	wait
237	Mia:	ok i got the tazi
238	Mia:	*taxi
239	Ellen:	ok
240	Ellen:	now wait, only ONE person edit the travel page at a time
241	Mia:	ok
242	Sam97:	ok

Figure 3: A transcript that demonstrates project markers.

In the segment of transcript shown in Figure 4, Joe plans to use the chat window as a scratch pad. This segment of chat was relevant to several discussions by the class. It demonstrates a problem with the initial design of CEDAR, but it also invites an interesting discussion about the papers on "awareness" that were read in class (Heath et al, 2002).

067	Joe:	I'm going to paste random urls that might be useful in the chat window in case I want to refer back to them later
068	Sally:	me too, since i cant have wicki's and other stuff open at once
069	Joe:	http://www.chi2006.org/call.php (location info)

Figure 4: A problem of awareness.

The initial replay device was very slow, so it was rebuilt. The students voluntarily developed an alternate kind of transcript anaylysis tool. A set of Unix shell scripts extracted and displayed the chat among the users in chronological order (see Figure 5). Interspersed between lines of chat are summaries of the edit and browser actions of the participants. This visualization is not as rich as a replay of a transcript, but is quite valuable for analyses that focus on the chat among the participants.

CS111 Transcript: Group106

Times are relative to the last event, in seconds. Note that even if you hide certain events,

☑ Chat ☑ Browser ☑ Editor

#	Time	User	Message
14	+11	Alice	you can use the site citysearch for montreal i think
15	+4	Alice	citysearch.com
16	+3	Bob	*CHANGE_URL* http://www.google.com
17	+8	Alice	a popular night street is crescent st/st. catherine
18	+16	Bob	okay, why don't you work on a page for entertainment?
19	+6	Alice	ok, ill get going
20	+0	Bob	I'll look up exact dates for conf
21	+16	Alice	*CHANGE_URL* http://www.johannari.net/mywiki/moin.cgi/group_
22	+5	Alice	GET group_106_entertainment (...)
23	+9	Bob	*CHANGE_URL* http://www.askjeeves.com
24	+3	Bob	*CHANGE_URL* http://www.askjeeves.com/
25	+0	Alice	GET group_106_entertainment (...)
26	+6	Bob	*CHANGE_URL* http://www.yahoo.com
27	+9	Alice	how do i use this editor?
28	+0	Bob	*HISTORY_URL* http://www.askjeeves.com/
29	+5	Bob	*HISTORY_URL* http://www.yahoo.com
30	+15	Bob	oops
31	+9	Bob	um, I think just type stuff, then hit post

Figure 5: Students create a tool for displaying a transcript.

The students also used the initial set of data as a basis for preparing their term project proposals. Each proposal was required to include at least one segment of transcript to illustrate their project idea. Examples of topics include: visualizing awareness between participants, division of labor, interruptions, and leadership within groups.

The class engaged in a redesign task. The plan was to redesign CEDAR for a second set of data collection exercises. Time constraints limited the changes that could be made to CEDAR, so as a result of class discussion only two additional features were implemented. A feature was added to the wiki editor that made it easier to manage the version history of each wiki page. A browser history button was added to the browser to simplify browsing on the Internet.

The Second Round of Data Collection and Analysis

The first data collection exercise was modified so it would provide a second set of transcripts. The goal here was to prevent the employment of a “divide-and-conquer” strategy among the team. This would encourage more interaction and joint sensemaking among the users.

In the new task, each team acted as an academic advisor who was required to develop a two-year schedule of classes for an incoming freshman. The task was to post in a timely fashion the student’s schedule for each year in chronological order. Half way through the session, the teams were interrupted (by the experimenters) and informed that their freshman advisee had decided to add a specific minor to her schedule. This required the teams to collaboratively revisit older parts of the schedule and modify them while continuing to work on planning the unfinished semesters.

This use of the technology helped the students to develop the scientific practice of experimental design. This also enabled them to produce data that would improve their project results.

We collected a second set of data using the new task and the modified version of CEDAR. This exercise provided the students with a more carefully engineered set of data better supporting their term projects. It also completed the redesign cycle by presenting the class with the opportunity to critically reflect on the tasks of interface design and experimental design.

For the term project, students could work alone or in pairs. Their task was to analyze the transcripts that had been collected in class and focus on some aspect of joint sensemaking. Students could do either an ethnographic or quantitative analysis. At the end of the semester the students turned in a 4000-word paper that described their project.

How CEDAR helped

The range, scope, and quality of the term projects is significant evidence that using collaborative technology to support reflection enabled students to participate at the interface of computation and social science. One project developed a graphic visualization of how closely a team was working together. Another project did an analysis of types of breakdown, their structure and detection. Several projects examined the dynamics of the online organization of the collaboration and its effects on coordination; for example, how did leadership emerge and affect the style of coordination within a group of collaborators? Other projects examine how the participants managed their ongoing conversation, both conversational floor and the maintenance of multiple simultaneous conversational threads. Yet another term project modeled the ebb and flow of awareness within a group of collaborators. Interruptions, the division of labor, and representational flow are other examples of topics selected by the students.

Overall it was an impressive list of topics. With but a few exceptions, the term projects uniformly demonstrated a superior understanding of many of the topics discussed in class. All of the projects included several detailed analyses of transcripts. The projects showed that the students were able to take abstract theoretical ideas and apply them to the close analysis of detailed transcripts of online activity. Without the in-class participation and practice at reading and analyzing transcripts, showing the relevance of theory to the dynamics and concreteness of online activity, it would have been much more difficult for students to make the leap – much of the class would have been lost.

Informally we assessed the effects of transcript analysis work on the progress of the students in understanding the theoretical material presented in the class.

- Students who did poorly on the first exam - which covered the theory part of the course - showed progress once they started to work closely with the data. Although they still had not achieved a deep understanding of the theoretical material, they made headway converting some of that material into practice.
- Students at the top of the class on the first exam produced write-ups on their term projects that showed significant progress at making sense of the theoretical material and relating those concepts to transcript analysis.
- The middle group of students all made progress. A number of these students who had been unable to clearly articulate the theories, especially on the first exam, showed significant improvement in understanding once they began to apply the topics to the transcripts they had collected.
- One of the term projects showed a very interesting analysis of the data, but failed to integrate their project with the theoretical material of the course.

At the end of the semester we handed out a survey to the students asking theoretical and practical questions about the course topics and structure, and value of the CEDAR technology.

- 93% of the students said that the CEDAR technology is useful for studying and applying the theoretical topics covered in the class.
- 82% of the students stated that having access to replayable transcripts made the theoretical papers read in class more comprehensible.
- 79% thought the availability of transcripts was helpful in choosing a topic for their term project.
- 82% believed that the second set of data was more relevant to their term projects.

- 75% believed that transcripts helped to focus the interface redesign task.

The survey also yielded the following representative comments from the students:

- "It helps you understand the task better to do it yourself. It gives more insight into how groups collaborate, how joint sense is achieved. It is easier to look at data from a task you are familiar with."
- "When we see the transcripts, the examples correlate with the theoretical stuff we read about. We can relate examples we see to the theory and challenge the theory."
- "Some of the papers were clarified or made concrete by examples from our transcripts."

Concluding Remarks

Participating critically at the interface of technology and the social sciences requires students to engage with relevant and meaningful materials as they alternate among a variety of means, modes, and methods for the study of technology in a context. In the case study presented in this paper, collaborative technology played a very significant role.

Students gained first hand experience with the "feel" of online collaborative work. Transcripts of these activities are objects of reflection and a rich source of data for the application of theoretical concepts and practical methods. In the classroom these transcripts can be used to authenticate theoretical concepts that otherwise might appear to be irrelevant or esoteric. The application of theoretical ideas to practical tasks like transcript analysis is a powerful educational technique for exploring the meaning and range of a set of ideas and also as a way to compare and contrast two alternate frameworks. The online environment in which the transcripts are collected is also an object of analysis. Critical skills can be developed through the close examination of mediated interactions provided by the environment and how it enables and frustrates user efforts. It is a worthwhile design problem and important classroom discussion to work out what is wrong with the interaction that is supported and how it should be redesigned. Experimental design is yet a third opportunity for reflection and analysis generated by the use of collaborative technology.

The case study shows that reflective collaborative technology can support education for the entire range of research and development activities, both theoretical and practical, from theory, to method, to evaluation. By creating objects of reflection and analysis, the technology provides students the opportunity to jointly focus in an analysis task within a changing zone of proximal development, participating at the interface of technology and social science.

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