

Computer-Supported Collaborative Learning
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Wikis to support the "collaborative" part of collaborative learning

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Abstract Prior research has highlighted the value of using wikis to support learning. This paper makes the case that the wiki has several properties that are particularly amenable for constructing applications that support the "collaborative" part of a variety and range of different time/different place student collaborations. In support of the argument, the paper presents the WikiDesignPlatform (WDP). The WDP supplies a suite of awareness, navigation, communication, transcription, and analysis components that provide additional functionality beyond the standard wiki feature set. Two case studies are presented, which have different coordination, communication, and awareness requirements for the "collaborative" part of the students' collaborative learning activities. The evidence shows that under both conditions, a prefabricated wiki provides a sufficiently rich intersubjective space that adequately supports the students' collaborative work.

Keywords Wikis · Asynchronous non-collocated collaborative learning · Coordination

Introduction

There are two issues to address in any kind of computer-supported collaborative learning (CSCL) activity. Did the students learn? Did the technology adequately support the students' collaboration? The latter question can be referred to as the "collaborative" part of collaborative learning, and it is the overarching theme of this paper.

Any computer-supported collaborative learning application combines a learning activity with a collaborative environment. The collaborative environment must enable students to

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create an online intersubjective space that adequately supports the students' cooperation. Building online environments that meet this criterion is not a trivial task.

Think of the intersubjective space in which the students operate as the "glue" that holds the collaborative learning activity together. It is what makes possible the functioning of the group. The space must be sufficiently rich so that students can carry out their joint learning task. How rich depends on how closely the students must work together. For some activities, *tightly coupled activities,* students must work within a joint problem space, which requires a detailed common understanding of the status of the problem. For other activities, *loosely coupled activities,* students must connect with one another to create some common ground but do not necessarily have to jointly focus on, or produce, a specific product.

Online collaborative systems can be divided up into a time space matrix: whether the collaboration is collocated or not and whether it is synchronous or asynchronous (Ellis et al. 1991). Collaborative learning activities can fit into any of the four possibilities. Each one has different requirements for the "collaborative" part of collaborative learning. Non-collocated asynchronous activities are of special value because they enable students to work together outside the classroom. Students may still have the opportunity to talk face-to-face, but potentially much of their collaboration emerges online in a virtual space where they are never really fully co-present at the same time in the same place.

Suppose students participated in several different online collaborative learning activities during a single semester. If both the activity and collaborative environment vary, the overhead of switching from one activity to another can be prohibitively high for non tech-savvy students. Applications developed for the same operating system, like Apple's Mac OS X®, share a similar look and interaction style. This is what makes it easier for users to switch back and forth between different applications. Similarly, it would help if there existed a platform or toolkit that could be used to compose different learning environments that would share the same style of interaction. Ideally, the platform and the interaction style would support a variety and range of different learning activities. A standardized platform of this sort would also provide a basis for the aggregation of techniques, learning activities, and research.

This paper makes the case that the basic wiki has several properties that make it an ideal framework for composing different time and place learning environments. Applications engineered within the style of wiki interactions can support a variety of learning activities ranging from tightly to loosely coupled collaborations. Wiki-based collaborative applications can also support metacognitive tasks, like reflection or self/co-explanation.

Two case studies are reported on in more detail. In the first study, students are working online in a tightly coupled collaboration; in the second study, the students' interactions are more loosely coupled. In tightly coupled learning activities, participants must jointly focus on key materials in a timely fashion as they collectively produce a product. The students must stay coordinated, especially on the key elements of their collaboration. Contributions lost in the interaction can potentially lead to degradation of performance. In loosely coupled collaborations, not every contribution must be recognized. Responses to contributions can be less timely. The sense of the common activity is less well defined and more distributed. The participants must be active, but their viewpoints require less convergence to maintain progress. The analysis of these two "radically" different kinds of collaborations focuses on characterizing, quantifying, and evaluating the "collaborative" part of the students' collaboration.

To support the argument of the paper, we present a wiki-based educational platform, the WikiDesignPlatform (WDP), developed in the GROUP lab at Brandeis University. The WDP provides a suite of transcription, analysis, awareness, navigation, and communication components that can be added to the basic wiki platform in order to produce more effective learning environments. New applications are custom-built by preformatting the structure of the wiki and adding components that further support, for example, coordination. The prefabricated wiki enriches the collaborative space making it easier for students to effectively and efficiently collaborate.

The WDP has been used to develop collaborative learning environments for a variety and range of educational activities for five courses taught at Brandeis University; Alterman was the instructor in each of these courses and Larusson the teaching assistant.

Wiki-style of interaction for different time/different place student learning

The standard wiki has several properties that are particularly amenable to building support for online different time/different place collaborative learning activities (see Table 1). The wiki is *Web 2.0 technology*. It is social and collaborative and the majority of today's student population is already familiar with technologies of this sort. The modest level of skills required to use Web 2.0 technologies makes it within the technical reach for both science and non-science students and teachers.

The wiki interaction (collaboration) style is primarily asynchronous. It is easy to *co-edit* documents as Web pages (wiki pages), which are *automatically published* online and thereby accessible to others at different times and places. There is a common syntax for articulation; for those who are less technically savvy, Web pages can be edited using WYSIWIG (**W**hat **Y**ou **S**ee **I**s **W**hat **Y**ou **G**et) text editors.

Wikis are *plastic:* It is easy to preformat them to support both a variety and range of collaborative learning activities. This enables the teacher to use the wiki structure as a mediating organization for how the students interact and coordinate their collaboration. By integrating scaffoldings specific to a given learning activity (Notari 2006), a wide range of learning paradigms can be implemented (Parker and Chao 2007; Duffy and Bruns 2006; Lamb 2004).

The *malleability* of wikis enables both teachers and students to do further adaptations to the environment so that it better aligns with the requirements of a particular class or the specifics of a given student or learning activity.

The wiki control structure is mostly *non-hierarchical*: There is not a centralized authority that controls the changes and additions to content. Students feel as if they work within a student-owned and centered workspace.

Table 1 Wiki properties particularly amenable to constructing different time/place collaborative learning applications

Property	Motivation
Web 2.0 technology	Within reach for experts and non-tech savvy students and teachers.
Document co-editing	Easy to asynchronously collaboratively produce content.
Automatic publication	Easy for students and teachers to share/exchange/access material.
Plasticity	Easy to preformat for a variety & range of collaborative learning activities.
Malleability	Easy for users other than developer to adapt environment.
Non-hierarchical control structure	Student-centered and owned workspace.

A platform that facilitates the construction of collaborative learning environments framed within the wiki's style of interaction has several benefits. Each new application shares the same common form of interaction making it easier for teachers and students to switch tasks within the same course. Thus, students can spend less time learning how to use the technology and more time learning the course material. A common standard of constructing learning applications can also simplify the aggregation of proven methods, designs, scaffolds, and strategies within the educational communities. Having the platform employ a more component-based architecture turns domains, learning activities, and collaborative environments into reusable components. Other components integrated with the wiki can provide additional functionality that increases awareness, improves navigation, and makes it easier to coordinate and create common ground. In general, reusable components simplify the process of (re-)engineering different learning environments tailored to the needs of any particular course or activity.

The "collaborative" part of collaborative learning

To function effectively, any kind of organization or community must share information relevant to its purpose. There must exist some kind of common understanding about shared activities, roles, and responsibilities, how to proceed in different situations, who will do what, how they will do it, what will be produced, and in what form. During an action, in response to some event, or as part of a planned activity, there are some common expectations about how things will be done. At each moment in time, the participants share some sense of what has happened so far and what will happen next. There will also be different understandings because of division of labor, status, or expertise. Different participants will understand things at different times and in different ways: This is part of the functioning of the community.

The lump sum of all of these things is the "glue" that holds the enterprise together – the intersubjective space in which the participants operate. It is partially biological. As humans, we have a perceptual apparatus that makes us see the world the same way. However, it is also social and cultural. Individuals have prior experiences, a history of activities, which characterize their current and future activities in the enterprise (Cole and Engeström 1993; Vygotsky 1978). The intersubjective space provides a background for interpreting the actions and motives of other participants. It is what we mutually believe a person means by what she does or says (Clark and Brennan 1991). It is the common "sense" of the interaction that emerges, but it is also those parts of what has occurred, is occurring, that are not mutually understood.

Two factors that make it difficult to manage the intersubjective space in online different time/different place collaborations are communication and coordination. In a face-to-face conversation, there is a wealth of information available that helps participants co-construct an intersubjective space. Online, the conditions under which the students communicate, coordinate, and establish common ground are significantly different. Much of the literature on collaborative technology is motivated by the problems of communication and coordination (Baecker 1993; *communication:* Tatar et al. 1990; Ellis et al. 1991; Turoff 1993; *coordination:* Malone and Crowston 1994; Schmidt and Simone 1996; Suchman and Trigg 1991).

Common ground is a part of what constitutes the intersubjective space. It is what the participants mutually believe about the situation (Clark 1996). Grounding is the method by which participants add new content to the common ground, which is established when the participants mutually believe they have understood what the contributor meant sufficient for current purposes (Clark 1996; Clark and Brennan 1991).

Because an online student community can be large and because all members are not always together at the same time in the same place, common ground emerges intermittently and non-uniformly. For example, on a wiki, a student can read a wiki page written by another student without confirming his or her understanding of the text. The students may have an overlapping understanding, but the degree to which it is the same is unknown. The wiki produces some convergence of understanding but not all is directly translatable into common ground. Because the students are multitasking and working in parallel, there is no time available for explicit, continuous, sequential grounding. The things that the individuals believe about a joint activity as a result of their online participation, mutually believed or not, are also a part of the intersubjective space (D'Andrade 1980).

The intersubjective space for an online activity depends on a representational system and practice (Hutchins 1995; Hutchins and Klausen 1996; Norman 1993). The representational system is composed of media, representational artifacts, and content, which mediate the functioning of the online collaboration (Perry 2003; Garfinkel 1967; Schegloff 1992). The representational system enables participants to make progress without grounding, maintain a shared view even when only some of what is understood at any time is common ground, and even when common ground varies among the community members (Alterman 2007).

Coordinating representations are an important part of the representational space (*coordinating mechanisms:* Schmidt and Simone 1996; *secondary artifacts:* Wartofsky 1979; *coordinating representations:* Suchman and Trigg 1991; Alterman 2007). A coordinating representation mediates an expected recurrent point of online coordination (Alterman, ibid). It is shared among participants and designed to make it easier for actors to work in parallel and multitask and make "common sense" of the situation and how to proceed with the action. They reduce the coordination work required to have a sufficiently rich intersubjective space. They enable actors to make progress, delay, or avoid the "face time" required for explicit grounding, and thereby enable forms of collaboration where the need to directly and sequentially interact is significantly reduced.

Although non-collocated students participating in an asynchronous online collaborative learning activity can periodically ground offline, and build the intersubjective space, much of the grounding work cannot emerge sequentially. By definition, the students' online interactions are interspersed with many other offline activities. Thus, the design of the collaborative environment, the representational system, and the coordinating representations it provides, is critical to the students' success.

The "problem" that the representational system must solve is not an easy one. When problems of coordination emerge, alternate forms of communication and interaction may be needed. Because the students are collaborating at a distance, they are not really directly focused on one another. At any given point in time, without adequate structure, the students' focus of attention is unlikely to be centered on the same thing. The collaborative environment must help the students stay aware of what is important, relevant, significant, and of interest. Sometimes students will also need to know when and where a particular event occurred.

The basic wiki provides some capabilities that can support coordination and communication in online different place and time collaborations. The plasticity of the wiki means its structure can be cognitively engineered to simplify coordination. Pre-structuring the wiki can make wiki pages function as a coordinating representation for specific recurrent activities among students: Later this feature will be used to help "engineer" the students' joint focus on particular significant tasks. The malleability of the wiki means that, irrespective of the initial structuring of the wiki, the teacher or students can make further adaptations to the wiki to meet their coordination requirements. The non-hierarchical control structure provides equal access for students. There is no complicated formulistic method of interaction required for students to co-edit and share representations within the same wiki space.

Because wiki pages are automatically published to the entire community, the coordination problems associated with sharing and distributing common representations is simplified. Compare how easy this is to do on a wiki, to how hard it is to when each student has individual paper copies of the same document. In the latter case, co-editing a document requires much more coordination work.

The basic wiki provides some components that help participants work together. The revision history enables users to see what pages have recently changed but is somewhat limited in the information it provides: It mostly focuses on edit changes. The discussion pages associated with each wiki page enables coauthors to communicate with one another but there are many situations where this kind of communication will not suffice. Without other forms of communication or coordination, it will frequently be difficult for students to keep up with current events and for one student to draw the attention of another student to a particular page on the wiki.

To better support a variety of learning activities ranging from loosely to tightly coupled collaborations, additional components must be added. These components can provide more appropriate ways of maintaining a shared view of their common work: a collaborative environment, an intersubjective space, which adequately supports the students' cooperation given the requirements of the task at hand. The claim of this paper is that by preformatting the basic wiki and selecting additional "appropriate" components to support, for example, communication and coordination, the basic wiki style of interaction provides a basis for building collaborative environments for a variety and range of different time and different place learning activities.

Depending on the learning activity, the basic wiki can be preformatted to scaffold and structure the students' collaboration and simplify their coordination work as they collaborate online. Additional communication methods help students maintain a common view of their joint enterprise outside the margins of the preformatted ways for students to interact. Additional awareness mechanisms enable students to "keep up" with new events on the wiki, especially ones that might be of particular interest to the student; thus the intersubjective space for a given student accretes in a manner that is relevant to the students' work. Improved navigation makes it easier for students to find relevant materials in a timely fashion. Scaffolding the wiki with project material turns the wiki structure into a mechanism that mediates and coordinates the students' cooperative work. Automated transcription and analysis tools for replaying the transcripts enable students to co-reflect on their online collaboration, engage in various metacognitive learning activities and provide a basis for research on online student collaboration.

The WikiDesignPlatform (WDP)

Wikis focus on enabling users to rapidly coauthor and share a collection of online free-form textual documents represented as Web pages or "wiki pages" (Leuf and Cunningham 2001). Wikis do not require any special software to use. Wiki pages are stored online, on the wiki, and are edited in an editor accessible through the standard Web browser. It is not necessary for the user to be familiar with complex HyperText Markup Language (HTML) tags in order to visually and structurally augment the wiki page content or "wikitext." The wikitext can be modified using a much simplified markup language called wikisyntax or by using a simple point-and-click WYSIWYG editor. A wiki maintains a revision history for all its coauthored pages, making it easy for users to revert a given wiki page back to a prior state. On a standard wiki, all users have equal rights and control over the content and structure. There is no set division of labor. The community does not have a director that instructs "workers" on what to do. Members pick the role that best matches their abilities and preferences.

The Wikipedia project is the most well-known example of wiki use. As of April 2009, the Wikipedia community has co-produced a total of 16,529,910 wiki pages, 2,851,000 of which are articles, in the English version of Wikipedia alone (Wikipedia Statistics 2009). These efforts go far beyond any attempts made by other encyclopedia projects (Forte and Bruckman 2006; Voss 2005). Wikipedia has incorporated some non-wiki-like regulatory frameworks mostly to prevent or revert vandalism (Viegas et al. 2004). Some users rank as moderators who can, for example, temporarily prevent further edits to a particular page and ban certain users.

The basic wiki environment is not sufficient in itself to support the variety and range of online learning activities that are beneficial to students beyond simple co-writing learning assignments. Despite its success outside education, it is not guaranteed that Wikipedia's collaboration style will succeed in an educational context (Ebner et al. 2006). If coupled with more educational-specific features, the basic wiki environment can support a larger variety of different time/different place collaborative learning activities (Tonkin 2005; Wang and Turner 2004; Raitman and Zhou 2005).

The recent workshop at CSCL 2007 (Lund 2007) and symposium at ICLS 2008 (Pierroux et al. 2008) give testimony to the growing interest in exploiting wiki-based technology in education. As a class website, or a research lab workspace, wikis afford the quick dissemination and discussion of teaching material (Bergin 2002; Tonkin 2005; Augar et al. 2004). Teachers can use wikis to share best practices and teaching materials (Da Lio et al. 2005). Favoring collaboration between geographically distant users makes wikis ideal for supporting many distance-learning programs (Schwartz et al. 2004; Bold 2006). Wiki-mediated collaboration requires students to mutually negotiate and agree on how to proceed with their coauthorship, which has significant educational value (Bruns and Humphreys 2005).

The more traditional educational uses of wikis include deploying them as a collaborative writing tool. Primary level students can construct a "choose your own adventure" book (Désilets and Paquet 2005). Students studying *English as a second language* can collaboratively write, and peer-review, articles written in English (Chang and Schallert 2005; Wang et al. 2005; Honegger 2005). Students can use wikis to collectively summarize and reflect on their joint mathematical problem solving work (Stahl et al. 2007; Stahl 2008). Students can use wikis to collectively prepare themselves for a field trip (e.g., to an art museum) and (with the right technological support) continue to build the wiki-based knowledge repository during the trip (Pierroux 2008).

Learning activities based on constructivistic principles can be converted into wiki-based activities (Forte and Bruckman 2006; Forte and Bruckman 2007), as can projects that invite students to discuss and "argue" about alternate views of the same material (Rick et al. 2002). Wikis can be a platform for students to participate in a knowledge community that coauthors encyclopedia-style articles on course topics (Guzdial et al. 2001; Rick and Guzdial 2006; Lund and Smørdal 2006).

The WDP

Much of the previous work on wikis in education has focused on "if" students learn after collaborating vis-à-vis a wiki rather than exploring the actual "collaborative" part of the wiki-mediated activity. The evaluation of the basic wiki as a platform for engineering applications to support a variety and range of different time and place online collaborative learning activities requires a systematic study of the space of possible collaborations.

The WikiDesignPlatform (WDP) has been used to build several different learning applications. Different WDP-based applications have been used within a single course to support different learning activities. This demonstrates that applications framed within the wiki's style of interaction have a relatively low learning overhead. The wide variety of learning activities demonstrates the plasticity of wikis. Each of these activities varies the requirements for how closely the students must work together and require different coordination, communication, and awareness capabilities. At one extreme, students must work closely together in a joint problem space; at the other extreme, the students' collaboration is more loosely coupled. In either case, the intersubjective space constructed using the WDP was effective as supporting the collaborative part of the online student work.

The WDP provides a suite of awareness, navigational, communicative, and analysis components and scaffolds. These components can be layered on top of, or coupled with, the WDP's core application: a customized MoinMoin wiki (Hermann and Waldmann 2008). The WDP's collection of components helps in composing wiki-based learning applications that provide support tailored to the specific collaborative needs of a given learning activity. Because the core of each application is the wiki, each application shares the same style of interaction.

Presented next is a discussion of the key components of the WDP platform. These components enable individual applications to be tailored to fit the goals of the learning activity. They also enable teachers (and researchers) to monitor and evaluate the students' online work. "Picking and choosing" the right components for a given learning activity is what creates an online intersubjective space that allows students to productively collaborate.

Preformatting the structure of the wiki

For a particular learning activity, the preformatted organization of the wiki has a dual function. It supports coordination and scaffolds the learning activity.

In education, *scaffolding* refers to the support, "devices," and/or "strategies" offered that guide students in carrying out their learning activity so as to maximize the educational "profit" (Collins 2006; van Merriënboer et al. 2003; Ward and Tiessen 1997). Scaffolding enables a novice/learner to tackle complex and difficult problems, which without assistance would be beyond the individual's abilities (Pea 2004). Without the right scaffolding, student collaborations are likely to be ineffective.

Incorporating scaffolding organizes the learning material into a meaningful structure embedded in the students' workspace (Wiley and Ash 2005). It helps the students develop mental models and/or representations of the target concepts, topics, and/or methods. Scaffolding also enables students to "assess" their progress and identify project and problem requirements, which in turn focuses their work on the most critical issues (Jonassen 1999).

Scaffolding can be offered as worked examples, learning agents, visual aids, and reference sources (Clark 2005). It can be a help system, provide guided tours or hints on how to proceed with a particular task (Collins 2006). Scaffolding can structure, define, or confine the students' work to emphasize on a specific important technique or method, for example, how to construct arguments and produce claims (Jonassen et al. 2005).

Scaffolding can also entail the application performing some less critical parts of an assignment, for example, arithmetic functions, enabling students to focus on (conceptually) solving the problem (Jonassen 1999; Collins 2006).

Scaffolding a wiki with project-related material creates a representational structure that guides and organizes the students' interactions, concentrated on the key aspects of their collaboration. The scaffolding functions as a coordinating representation, which helps the students coordinate and share a common view of their cooperative activity.

The WDP provides no special "scaffolding toolkit" beyond the fact that wikis are easy to prefabricate. However, collecting modifiable scaffoldings that can be reused on the same platform in conjunction with components that support, for example, communication or awareness benefits students and teachers alike. Students can engage in a variety of educational tasks within a common framework; the alternative, requiring students to learn a new interaction style for each new activity introduces a significant overhead that can interfere with their learning. Teachers and researchers have a common parlance for exchanging proven ideas and developing new techniques. A platform of this sort provides teachers with a repository of ready-made scaffolds, components, and learning activities that can be more easily "borrowed" and adapted to the specifics of a particular student, course, or project.

One of the studies presented in this paper explores scaffolding designed to support students engaged in a collaborative design project in a Human-Computer Interaction (HCI) class. Figures 1 and 2 show an excerpt from the prefabricated wiki offered to the students.

The scaffolding included among other things: example checklists, surveys, and prototypes. The role of the scaffolding was to organize, coordinate, and guide the students' design work so that they jointly focused on, and problem solved, the most critical project issues. Figure 1 shows the project task list. By clicking through the list, students can obtain more detailed information on a particular subtask including editable templates. Figure 2 shows an example template preloaded with "hints" that show students how to use it.

Awareness and navigation

Most wikis include a "recent changes" page that summarizes recent page edits and helps users stay coordinated. While this component provides valuable information, it has some limitations. Students not only need to keep up-to-date on who is editing what but also if

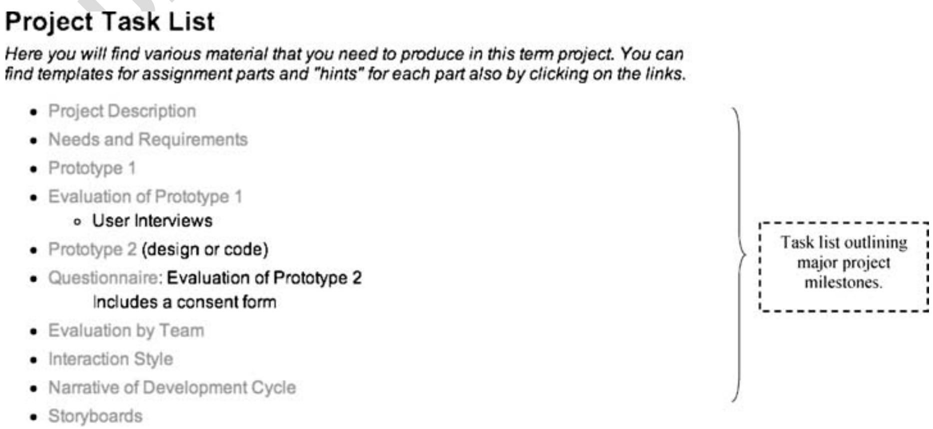
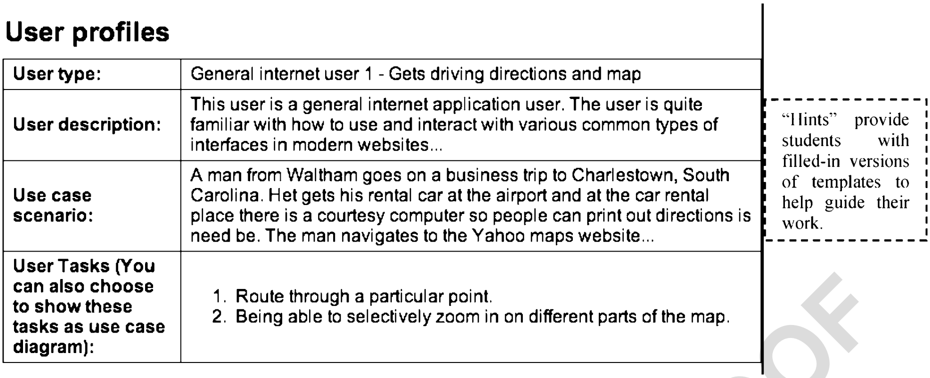


Fig. 1 The project task list enumerates all the critical milestones in the project


User profiles

User type:	General internet user 1 - Gets driving directions and map
User description:	This user is a general internet application user. The user is quite familiar with how to use and interact with various common types of interfaces in modern websites...
Use case scenario:	A man from Waltham goes on a business trip to Charlestown, South Carolina. Het gets his rental car at the airport and at the car rental place there is a courtesy computer so people can print out directions is need be. The man navigates to the Yahoo maps website...
User Tasks (You can also choose to show these tasks as use case diagram):	1. Route through a particular point. 2. Being able to selectively zoom in on different parts of the map.

Fig. 2 Editable templates are provided along with "hints" on how to "fill in" each template

other students are actually paying attention to (reading) what they are writing on the wiki. For example, structural overview maps can heighten the students' awareness of recent activity on the wiki and simplify accessibility and navigation to content (Reinhold 2006; Reinhold and Abawi 2006; Ullman and Kay 2007; Han and Kim 2005).

The WDP provides two awareness components: the WikiNewsletter and the WikiEye. Both components enable a student to move directly from a notification of a contribution to its location on the wiki. These components answer important questions such as "who has read what I wrote?" which helps students organize and coordinate their collaborative task and determine how "closely" the group is working together.

The WikiNewsletter (Fig. 3) is an email message that is sent out daily to all wiki users and highlights activity and changes on the wiki in the preceding 24 hours. The newsletter is push-technology (Nuschke and Jiang 2007). The newsletter does not require students to login to the wiki. The vocabulary of each newsletter is tailored to fit the learning activity. For example, on a WDP-based co-blogging environment, the newsletter can describe edit events on discussion pages as "*Bob commented on Caroline's blog"* instead of *"Bob edited a page."*

The WikiEye (Fig. 4) provides an on-demand tabular formatted summary of recent activity on the wiki. It summarizes both editing and reading activities by each individual user. It also provides information on pages that have been recently created or deleted, recently uploaded files, and WikiStickies. Viewing options enable the student to filter the information by selecting a user, time period, or tag of interest.

Communication

The WDP provides components that support communication beyond the "standard" set: one example is email, a second is instant messaging (IM), and a third is the WikiSticky. When a new learning activity is constructed, the preferred communication components are fully integrated into the environment. Full integration not only means that students can communicate vis-à-vis the wiki or third party applications but that their communicative product is stored on the wiki and accessible by students and teachers alike for later review. The communication discourse can be searched, tagged, and linked to just like a traditional wiki page.

WikiStickies (Fig. 5) are "Post-it®" like notes that users can embed inside a wiki page. They are easily distinguishable from the permanent page text and can be addressed to a specific target audience. WikiStickies addressed to a student, either individually or as a part of a group, will show up on his or her WikiEye and newsletter.

Fig. 3 The WikiNewsletter describing recent activity on a co-blog wiki

Transcription

All of the collaborative platforms we have developed automatically produce replayable and reviewable transcripts of the students' online activities. The production of transcripts serves a range of theoretical and practical functions (Alterman and Larusson 2007):

1. The exercise of collecting and analyzing transcripts teaches experimental design and methods.

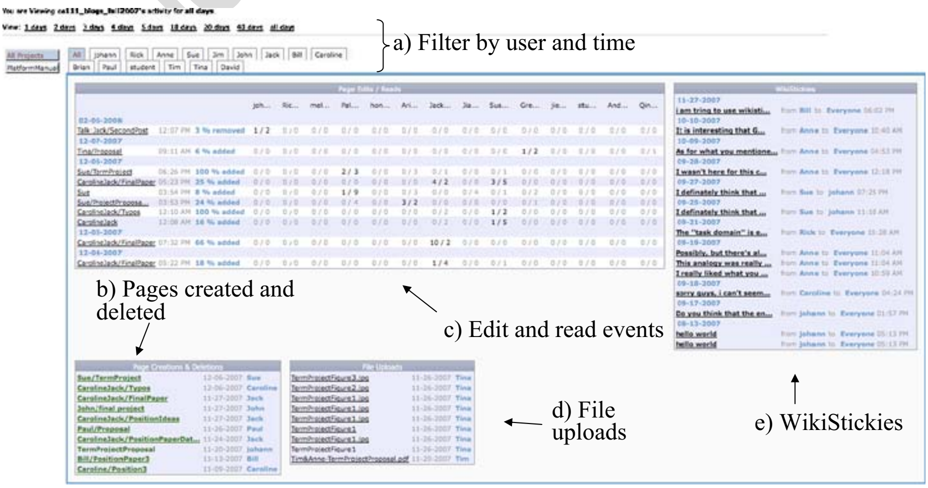
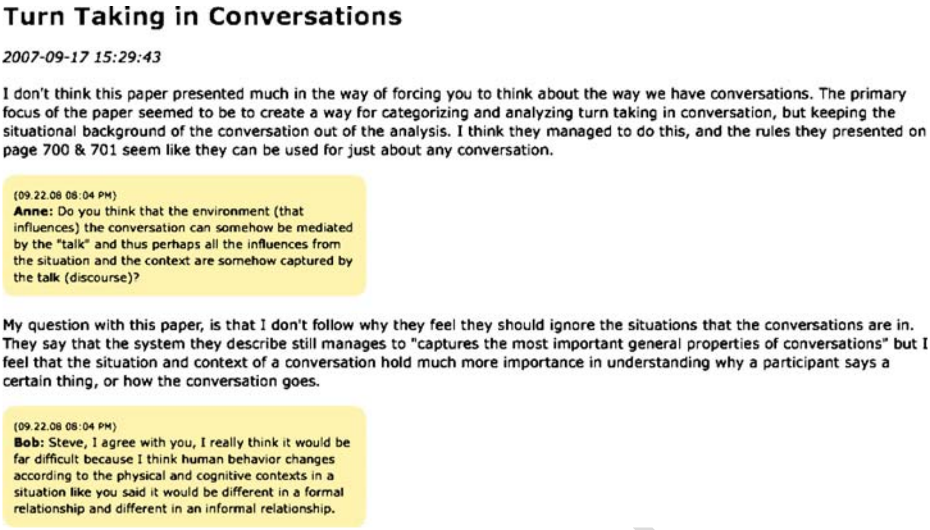


Fig. 4 The WikiEye awareness mechanism


Turn Taking in Conversations

2007-09-17 15:29:43

I don't think this paper presented much in the way of forcing you to think about the way we have conversations. The primary focus of the paper seemed to be to create a way for categorizing and analyzing turn taking in conversation, but keeping the situational background of the conversation out of the analysis. I think they managed to do this, and the rules they presented on page 700 & 701 seem like they can be used for just about any conversation.

(09.22.08 08:04 PM)
Anne: Do you think that the environment (that influences) the conversation can somehow be mediated by the "talk" and thus perhaps all the influences from the situation and the context are somehow captured by the talk (discourse)?

My question with this paper, is that I don't follow why they feel they should ignore the situations that the conversations are in. They say that the system they describe still manages to "captures the most important general properties of conversations" but I feel that the situation and context of a conversation hold much more importance in understanding why a participant says a certain thing, or how the conversation goes.

(09.22.08 08:04 PM)
Bob: Steve, I agree with you, I really think it would be far difficult because I think human behavior changes according to the physical and cognitive contexts in a situation like you said it would be different in a formal relationship and different in an informal relationship.

Fig. 5 A wiki page with WikiStickies embedded within the page content

2. The students' participation in data collection exercises gives them firsthand experiences with online collaboration.
3. The firsthand experience of students as both collectors of data and participants in online collaborative activities 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.

For students, the transcripts are objects of reflection. Students can study transcripts of their own online collaborations. Their analysis is grounded in their own experiences as they try to interpret the collaborative activity (Boyd and Fales 1983). Providing students with reviewable records (transcripts) of their prior online problem-solving activities also enables them to work on their metacognitive strategies for controlling their self-regulatory problem-solving processes (Azevedo 2005a, 2005b).

For researchers, the transcripts provide a valuable source of data. The transcripts make it possible to identify new characteristics of events that indicate what kinds of, and the extent to which, the students interact online. Being able to model the mechanics of the students' online activities is a precursor to a more effective approach to designing technology to support online student collaborations.

For teachers, transcripts of the students' own collaborations can be used during lectures as "texts" to help make complex theoretical material more concrete.

In one course, the students analyzed their own transcripts as a part of their term project (Alterman and Larusson 2007). On a survey, the students rated the educational value of the transcripts. There were 29 students in the class. About half of the class (n= 14) consisted of undergraduate students and the majority of the class (n=26) included graduate students and undergraduate majors in Computer Science. The survey questions were organized as simple yes/no questions. Eighty-two percent of the students stated that having access to replayable transcripts made the theoretical papers read in class more comprehensible. Seventy-nine percent stated that being able to review transcripts of actual collaborations was helpful when choosing a topic for their term project. Eighty-two percent stated that the transcripts were valuable for their term projects. 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."

The students were provided with an analysis tool that replayed their online activities at the interface level. One student voluntarily developed (and shared with the class) a small program, which provided an alternate view of the same data. These scripts focused on displaying the chat among the wiki users in chronological order (see Fig. 6). 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 communication (chat) among the participants.

Technical details

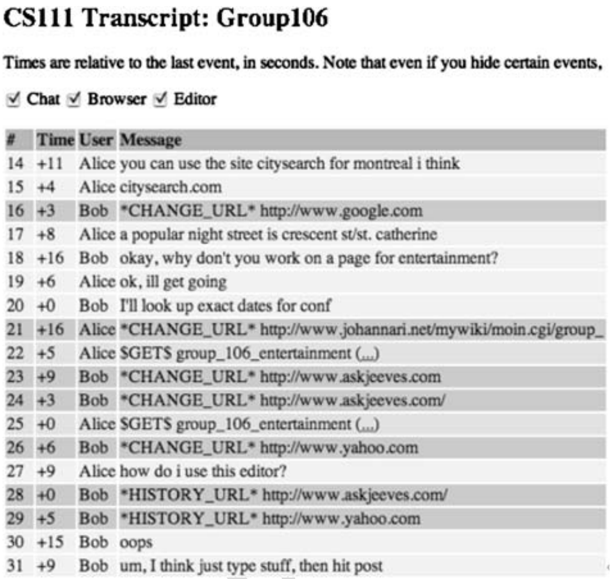
In addition to edit events, the WDP transcripts describe more activities, and in greater detail, compared to the standard wiki revision history. The transcripts are raw XML files (Fig. 7) where each element represents a type of an event (read, edit, WikiEye navigation, tagging a page,…).

The transcripts can be treated as an event log file, imported into a traditional relational database, and examined by writing SQL queries and small scripts. The WDP provides additional tools that enable a larger variety of alternate analysis methods: from discourse, conversation, or interaction analysis to ethnography. For example, the WikiPlayer replays the transcripts just as if one was viewing a videotape (Larusson and Alterman 2007, 2008). The Wikiplayer enables students or teachers to engage in "on-the-fly" interaction with the data, filtering, searching, and spontaneous exploration of the evolution of individual pages and the wiki as a whole.

Variety of learning functions

Wiki-style learning environments built using the WDP have been deployed on more than one occasion in different capacities (see Table 2) in a number of courses taught by the authors in the Computer Science Department at Brandeis University.

The WDP has regularly been used to construct a *class website* for "managing" the course (see Function 1 in Table 2). The class website is mainly used as a "distribution channel" for course material and as a coordination medium for scheduling class activities. Emails sent through the class mailing list are also viewable, searchable, and taggable on the class wiki. All in all, the students, instructor, and teaching assistant only need to go to a single location to obtain all the material pertinent to the course. Because of the wiki's low technical



CS111 Transcript: Group106

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

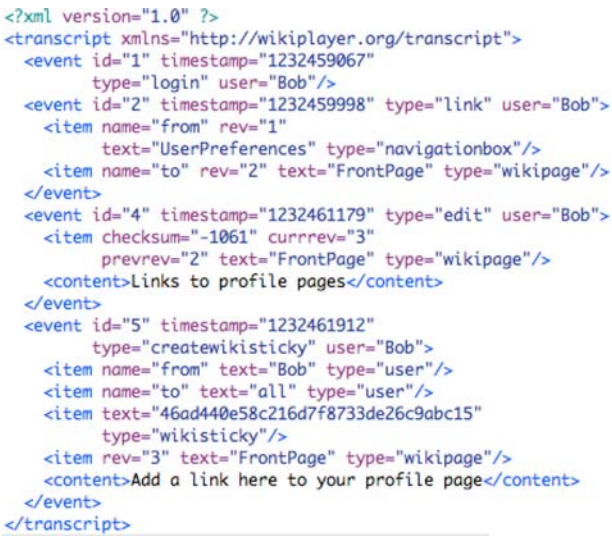
☑ Chat ☑ Browser ☑ Editor

#	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	$GETS group_106_entertainment (...)
23	+9	Bob	*CHANGE_URL* http://www.askjeeves.com
24	+3	Bob	*CHANGE_URL* http://www.askjeeves.com/
25	+0	Alice	$GETS 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

Fig. 6 A transcript analysis tool created by a student

overhead, interacting with the class website is within reach for non tech-savvy students and teachers. Both the students and the teacher can easily and quickly upload and download files and change the wiki page content. The WDP's awareness mechanisms help the students keep up-to-date on when new material has been posted by the instructor and teaching assistant.

In several courses, students have *co-blogged* on the course material using an environment constructed with the WDP platform (see Function 2 in Table 2). Each student has to write blog posts on topics covered in the course. The students also comment on each other's blog posts. The blog wiki is prefabricated to meet the needs of this learning task, but the students still use the same "familiar" wiki style of interaction. Editing wiki pages is a



```xml
<?xml version="1.0" ?>
<transcript xmlns="http://wikiplayer.org/transcript">
  <event id="1" timestamp="1232459067"
         type="login" user="Bob"/>
  <event id="2" timestamp="1232459998" type="link" user="Bob">
    <item name="from" rev="1"
          text="UserPreferences" type="navigationbox"/>
    <item name="to" rev="2" text="FrontPage" type="wikipage"/>
  </event>
  <event id="4" timestamp="1232461179" type="edit" user="Bob">
    <item checksum="-1061" currrev="3"
          prevrev="2" text="FrontPage" type="wikipage"/>
    <content>Links to profile pages</content>
  </event>
  <event id="5" timestamp="1232461912"
         type="createwikisticky" user="Bob">
    <item name="from" text="Bob" type="user"/>
    <item name="to" text="all" type="user"/>
    <item text="46ad440e58c216d7f8733de26c9abc15"
          type="wikisticky"/>
    <item rev="3" text="FrontPage" type="wikipage"/>
    <content>Add a link here to your profile page</content>
  </event>
</transcript>
```

Fig. 7 Excerpt from a transcript describing Bob's activities on a WDP-based wiki

Table 2 Different kinds of WDP-based applications and the types of learning activities it supported

No.	WDP's function	Wiki features
1	Class website	Awareness and navigation, communication (email), and scaffolding for organizing a class website.
2	Co-blogging	Awareness to help students keep current of new relevant events as they reflect on and discuss the course material.
3	Use WDP platform to cognitively engineer CSCL platforms.	Malleability and suite of WDP components for students to design scaffolds and prototype CSCL environments.
4	Workspace for collaborative design term project	Scaffolding and awareness to support coordination and co-editing of wiki pages.

means of writing, or commenting on, blog posts. Using WikiStickies, the students' comments are easily located on the blog posts and are highlighted on the WikiEye. The WikiNewsletter also helps students keep current on new events in the blog-o-sphere.

In other courses, teams of students used the WDP toolkit themselves to *cognitively engineer prototype collaborative learning environments* (Function 3 in Table 2). Students re-format the wiki pages (create new kinds of scaffoldings) to reflect their design ideas for a particular collaborative learning task/application. Students also select from the WDP's suite of components (e.g., awareness or communication components) that best match their design ideas. Because the prototype environment is constructed using the WDP platform, the transcripts and analysis tools enable the students to collect valuable data that can fuel further redesigns.

In an HCI course, the WDP was used to construct a wiki-based *workspace* that supported students participating in team-based design term projects. Students used the wiki environment to manage their work and as a central repository for (coauthored) documents related to their interface design (Function 4 in Table 2). The wiki was pre-scaffolded with example checklists, evaluation methods, and editable templates with "fill-in hints" so students could more easily organize and concentrate their work on the important tasks defined by the teacher (see Figs. 1 and 2 for an example of the scaffolding offered for this course). Coupling the wiki with email and CVS code repository components enabled students to more easily communicate and distribute material as they asynchronously developed ideas and code.

Because the WDP was used to build all of these applications, the students only needed to learn one style of interaction — the *wiki style* — and could more readily switch between different learning activities within the same course. For example, in one course students first used the WDP as class website, then as co-blog platform, and finally as a cognitive engineering platform.

Two case studies

This section reports on two case studies that explore the capability of using wiki-based learning environments to support both tightly and loosely coupled learning activities. The analyses use data collected in classes taught a Brandeis University. Alterman was the teacher in both courses and Larusson the teaching assistant. These courses are not "traditional" Computer Science courses. The course material is conceptually difficult and highly interdisciplinary (see Table 3). The goal is to produce students who can design/

Table 3 Study draws on data from these technology-oriented courses taught at Brandeis

Course	Topics	Class work
Human Computer Interaction (CS25)	Theory, concepts, and methods for developing computer-mediated activities.	WDP mediated HCI team design term projects.
Computational Cognitive Science (CS111)	Cognitive and Social theories of individual and collective activity.	Entire class co-blogs on course material on the same WDP wiki.

develop technology within a critical framework and participate at the interface of technology, social sciences, and the humanities.

For the class where students were engaged in a tightly coupled learning activity, they were working in teams on a HCI design term project. The students collaboratively produced a particular product using design methods taught in class. Ideally, the students stayed jointly focused on the critical elements of the project and shared a common view of who was doing what and when, what needed to be done, and the evolving product of their efforts. The students needed to maintain awareness and be responsive, in a timely fashion, to contributions by other students. Knowing that your contribution was read or further edited was an integral element of the task. Performance depended significantly on honoring commitments.

The co-blogging activity was a more loosely coupled activity. The goal was for students to articulate in their own words their understanding of the course material, developing their individual viewpoints, and commenting other explanations of the same material. The students worked intermittently, at their convenience, throughout the week. Some level of awareness was needed for online discussions to regularly emerge. However, it was not necessary that the students read every contribution to the blog-o-sphere; this is in direct contrast to the case of the tightly coupled activity.

Content on the wiki is only accessible to users that are logged in. Only the students, the instructor, and teaching assistant have login accounts on the wiki. When students log in for the first time they are presented with a disclaimer explaining that their online activities will be automatically recorded into transcripts. Students can then choose to sign a consent form permitting the use of their transcripts in future research. For the studies reported on in this paper, all of the students gave permission for their transcripts to be analyzed.

The transcripts that are automatically produced by the WDP were the basis of our analysis of the students' online activities. The transcripts enable the analyst to track read, edit, and navigation events. When a student navigates to a wiki page, he or she is considered to be reading that page. Students may "visit" a page only to navigate to another page. However, because wiki pages that, for example, contain blog posts tend to be leaves on the link hierarchy of a blog wiki, visiting a leaf node is a reasonable heuristic for measuring whether a page, or some portion of a page, was read. Interactions between the students obviously also occurred offline, nevertheless the transcripts tell an important story about the character and quality of the online intersubjective space in which the students operated.

Tightly coupled collaborations in a team design project

The WDP was used to construct a wiki-style collaborative workspace that enabled students to participate in a tightly coupled learning activity even though their interaction was primarily asynchronous. Coupling the WikiEye awareness mechanism with the wiki enabled each student to more easily stay aware of new contributions made to the workspace and determine when and if other team members were reading/responding to their contributions.

The wiki was also prefabricated with scaffolding that encoded the online representational system with design techniques, methods, examples, "fill-in" templates, and rules of thumb that structured the students' work so as to approximate a "normal" design process (refer to Figs. 1 and 2 for examples). Each of the key learning elements of the design project was "laid out" on separate wiki pages. At any given point in time, the "current states" of these wiki pages were an external representation of the status of the *joint problem space* (Roschelle and Teasley 1995).

Much of the prefabrication was intended to function as coordinating representations that organized the interaction among student team members so they centered their cooperation on the significant elements of the design project. There was nothing exotic about the layout of the workspace that each team used. At issue was whether the students found it worth their time to use the wiki and whether the scaffolding helped each team share a joint focus on the critical elements of the assignment and coordinate their efforts.

The scaffolding consisted of three template pages, seven example pages, and seven "other" scaffolding pages that served to organize other kinds of student output or the collaboration itself:

Examples: Examples of what specific design tools look like, such as a storyboard or a questionnaire.

Templates: "Fill-in-the-blanks" that the student could use to complete a design task like identifying user needs and requirements.

"Other" scaffolding pages: For example, a to-do list that organizes the student project or an exemplar of the structure of the final project report.

Most scaffolding pages included "*hints*" that provided further information on a particular subtask, for example, guidelines on how to fill-in a particular template.

The evidence will show that although the students' wiki-mediated tightly coupled collaborations were asynchronous and non-collocated, they nevertheless operated within a close joint problem space. The students shared a joint focus on the important design problems and other term project material. The evidence will also show that teams larger than two students were more likely to collaborate online and that the scaffolding did function as coordinating representations between larger teams.

Participants

There were 18 undergraduate students in the HCI team design project course (CS25). There were 8 Computer Science majors, 2 other science majors, and 8 students from the social sciences. The majority of the students in the class (n=14) were males.

The term projects were done in self-selected teams with a maximum size for a team of four students. There were two teams of four students, two teams of three students, and two teams consisting of two students each. The four females ended up being on different teams. Each team was assigned a prefabricated WDP wiki.

As an introductory course open to non-majors, the technical requirements for enrollment were few. No formal evaluations were done to assess the students' computer literacy. In class discussions, most of the students expressed moderate or advanced technical skills. The majority of the students claimed prior experiences with collaboration but none had engaged in extensive online team-based collaborations.

Procedure

Earlier in the semester, the students were introduced to the class wiki, a tour of the wiki's features was provided. The students completed an in-class exercise that introduced them to the significant features of the class wiki. Minor additional *training* was provided when students began to work on their projects. The major difference between the class wiki and the team wikis concerned the scaffolding and the use of the WikiEye. The teaching assistant provided a brief tour during a single lecture that introduced students to the organization of the team wiki workspaces.

The students worked for 4 weeks on their projects primarily outside lecture hours. Their choice was to meet face-to-face, collaborate online, or do both. Some time was set-aside during lectures for students to discuss or present their progress and get feedback. In addition to regular office hours, the instructor and teaching assistant organized a couple of additional face-to-face meetings where students could present their work, ask questions on issues they were struggling with, and get further feedback on their designs.

Metrics

The analysis of each team's collaboration will focus on evaluating whether or not the tightly coupled students shared a joint focus on the critical elements of the project and operated within an online joint problem space. The number of students who edit a given wiki page (*editors*) and the number of times a page is edited (*edit turns)* are measures relevant to determining whether the students worked within a joint problem space:

Editor: A student who edits a wiki page is considered to be an *editor.*

Edit turn: An *edit turn* begins when one student edits a page and ends when the contribution is acknowledged by at least one other student as he or she either reads or re-edits the contribution. See Fig. 8 for an example of a page that received multiple edit turns from different students.

If students divide-and-conquer their collaborative project, there will be a preponderance of wiki pages where only one student edited the page or where final versions of wiki pages received only a few edit turns. In the worst-case scenario, there is only a single student editor and a single edit turn on each of the scaffolding pages; the students would not operate closely within a joint problem space.

Editing student created pages

On average, the students created 5.67 pages in addition to the scaffolding pages. Many of these pages presented material that was not easily editable on the wiki so they had to be created elsewhere and uploaded to the wiki. For example, because drawings cannot be easily designed and modified on the wiki, students used other desktop applications to develop the drawings, which they subsequently uploaded to the team's wiki for distribution purposes. These pages were also used as temporary storage spaces for material collected offline that was later migrated into other locations, for example, templates, on wiki.

Joint problem space?

The prefabricated structure for the team workspaces highlighted the crucial elements of their design activity. Twelve of the 17 scaffolding pages were the most important in terms

Page: Needs and Requirements/UserProfiles		
Line	Event	No. of edit turns
1	Bob edited at 2006-10-30 19:27:16	1st edit turn
2	Chris read at 2006-11-01 21:54:15	
3	John read at 2006-11-01 01:13:32	
4	Chris edited at 2006-11-01 22:06:45	2nd edit turn
5	John read at 2006-11-14 19:19:19	
6	Steve read at 2006-11-15 09:42:56	
7	Steve edited at 2006-11-15 09:44:46	3rd edit turn
8	Chris read at 2006-11-19 17:25:14	
9	John read at 2006-11-19 14:17:00	
10	Bob read at 2006-11-19 16:57:36	
11	Bob edited at 2006-11-19 19:20:04	4th edit turn
12	Steve read at 2006-11-26 10:58:59	
13	Steve edited at 2006-11-26 11:16:19	5th edit turn
14	John read at 2006-11-27 00:00:32	

Fig. 8 Example of a page that received five edit turns

of design: all three template pages, six example pages and three of the other scaffolding pages. Ideally, these would be the wiki pages that multiple students would co-edit. Some of the scaffolding pages are less likely candidates for co-editing. Other scaffolding pages, like the front page of each team's wiki, which provided a "hierarchical link structure/overview" into the various parts of the assignment were co-edited by the students to improve coordination among team members.

All metrics showing averages per team size are computed as shown in the following example (see Eq. 1). Assume there are 17 scaffolding pages (n= 17). Let $Editors_i$ be the number of *different* editors on any given scaffolding page i. Thus, the average number of different editors on n scaffolding pages for any given team is:

$$\overline{Editors} = \frac{1}{n}\sum\nolimits_{i=1}^{n} Editors_i \qquad (1)$$

The average number of edit turns can also be computed in a similar fashion. The average number of editors or edit turns on scaffolding pages in teams of a particular size is computed by averaging the results from the equation above for each team of that size.

The teams edited, on average, 94% of the template pages and 81% of the example pages. Five of the six teams edited all of the template pages. Table 4 summarizes the average number of editors on the scaffolding pages. Across all teams, the majority of the students edited the scaffolding pages. For larger teams of four, there were on average three editors per each scaffolding page. The fact that the majority of the teams co-edited the scaffolding pages suggests that the students in each team were jointly focused on the same critical elements of their project.

Table 5 summarizes the number of edit turns on the wiki pages. The scaffolding pages received, on average, more edit turns than the pages created by the students. Each scaffolding page had on average 4 edit turns whereas the pages that the students created received on average 2.8 edit turns. The high number of *editors* per scaffolding page indicates that the students were jointly focused on the crucial parts of the assignment. However, the fact that these same pages received, on average, multiple *edit turns* from different users is evidence that the students were jointly problem solving on the key (learning) elements of the project.

Table 4 Avg. number of editors per pages

Metric	Teams of 4	Teams of 3	Teams of 2
Co-edit scaffolding pages			
Avg. no. editors on all scaffolding page	3.0	1.9	1.4
Avg. no. editors on template pages	3.2	1.8	1
Avg. no. editors on example pages	2.3	2.1	1.1
Avg. no. editors on other scaffolding pages	3.5	2.0	2.0
Co-edit student created pages			
Avg. no. editors on student created pages	1.7	1.4	1.2

Scaffolding as coordinating representations

Because the students in the tightly coupled activity are jointly producing a particular product, their success depends on the team staying sufficiently coordinated. Scheduling a time and place to meet, offline, is much easier to accomplish for smaller teams. If the analysis of the data shows that the larger teams used the wiki more often, they substitute online collaboration for some face-to-face meetings, and their focus was on the important elements of the project — namely the scaffolding pages — then there is confirming evidence that the wiki was effectively supporting the "collaborative" part of the team term project.

We explored potential relationships between team sizes and how much, and how often (edit turns), their collaboration involved co-editing the scaffolding pages (see Table 6).

On average, the larger teams co-edited more of the scaffolding pages (see line 1). They also exhibited more edit turns on all wiki pages (see line 2). For example, teams of four students had a total of 234 edit turns compared to a total of 29 edit turns for teams of two students. Similarly, the total number of edit turns on the scaffolding pages were much greater for the larger teams (see line 3) who were also more likely to do multiple edits on all wiki pages (see line 4). The larger teams had a total of 37 wiki pages that were edited multiple times by different students whereas teams of two students only had seven pages that were edited multiple times by both members of the team. The larger teams were also more likely to do multiple edits on the scaffolding pages (see line 5).

A Pearson correlation test confirmed that the relationship between team sizes and each of the metrics shown in Table 6 was statistically significant with $p<.05$. In general, larger teams were more likely to use the wiki to coordinate and collaborate.

The scaffolding was intended to help the students, particularly the larger teams, to coordinate and share a common view of their cooperative activity. The fact that the larger teams' collaboration centered on the scaffolding pages gives testimony to the importance of providing scaffolding in asynchronous non-collocated learning environments. The provided examples and templates highlight their function as coordinating representations.

Table 5 Average no. of edit turns by team size

Metric	Teams of 4	Teams of 3	Teams of 2
Avg. no. edit turns on all scaffolding pages	6.7	3.2	2.1
Avg. no. edit turns on important scaffolding pages	6.1	2.2	0.6
Avg. no. edit turns on student created pages	3.8	3.0	1.7
Avg. total no. edit turns on scaffolding pages	96	38	9.5
Avg. total no. edit turns on student created pages	21	10	5

Table 6 The students' collaborative wiki work in relation to team size

Line	Metric	Teams of 4	Teams of 3	Teams of 2
1	Avg. % scaffolding pages edited	97%	85%	59%
2	Total edit turns	234	96	29
3	Total edit turns on scaffolding pages	192	76	20
4	Total no. of pages with multiple edits	37	20	7
5	Total no. of scaffolding pages with multiple edits	30	19	5

Loosely coupled collaborations and the blog-o-sphere

The WDP was used to construct a wiki-style environment for students to co-blog on the course readings. The front page of the wiki listed the most recently added blog posts. WikiStickies enabled the students to easily write comments, and locate them, on each other's blog posts. The WikiNewsletter enabled students to stay aware of recently added contributions specifically on days when they did not contribute to the blog-o-sphere.

Co-blogging is an example of a loosely coupled collaborative learning activity. In a co-blogging exercise, each student has a *blog*. Each blog is composed of multiple *blog posts*. Students can read each other's blog posts and *comment* on them. In a co-blogging activity, students ideally develop their own opinions but also engage in "conversations" about other students' ideas by commenting on their blog posts. During any period of the semester, multiple conversations can emerge. The blogging part of a co-blogging activity makes the students explain in their own words the course material. The "co-" part of co-blogging makes the students exchange ideas and interact over the course material.

How does one measure the "collaborative" part of the students' wiki-mediated co-blogging work? Ideally, all of the student blogs should have an audience but each blog does not have to be read by every single student. Most of the blog posts should be read by somebody but it is not necessary for the same student to read all the posts or all posts by a specific author. Ideally, conversations emerge frequently within the blog-o-sphere with a reasonable subset of more extensive conversations (multiple comments by multiple students). Each student has to feel as if he or she was "heard" on a regular basis and that their contributions draw responses from other students. Who the "others" are can vary.

The analysis that follows closely examines the "co-" part of a wiki-mediated co-blogging activity. The evidence will show that students regularly produced blog posts and that the majority of the blogs were regularly read. The data will also show that the students' commenting and reading activities were extensive and that students not only read the responses to their own posts or comments, but they also read blog posts for which they did not generate comments. The evidence shows that students read comments and responses to comments that they did not produce and that many of the conversations received contributions from multiple students.

Blogging to learn

Blogging has been shown to be conducive to learning (Du and Wagner 2005). Because blogs are easy to use and quite popular, they offer new opportunities for engaging students and extending the learning process outside the physical classroom (Glogoff 2005; Duffy 2008). Blogs create a middle space between traditional classrooms, which tend to be instructor-centered, and online spaces, which are both student-owned and social (Oravec

2003; Deitering and Huston 2004). Because each student has a blog, students have full control over the content and establish a personal and intellectual ownership of their work (Ferdig and Trammel 2004).

Because blogs are "informal" they encourage students to explore and publish their own nascent ideas under less pressure than in the rough-and-tumble of in-class discussions (Althaus 1997). Because blogs are publically available, students not only write to learn but participate in a social activity. Writing a blog forces students to become analytic and critical as they contemplate how their ideas may be perceived by others (Williams and Jacobs 2004). By reading each other's blog posts, students can further develop their positions in the context of each other's writing by sensing how others understand the material (Oravec 2002). Conversations emerge when students comment on each other's blog posts.

Student co-blogging creates opportunities for students to exchange, explore, and present alternate viewpoints on the course material (Ferdig and Trammel 2004). With co-blogging, an epistemic dialogue can emerge (c.f. de Vries et al. 2002). Having students discuss, argue, and collaboratively reason about the course content positively impacts their learning (Andriessen 2006; Andriessen et al. 2003; Reznitskaya et al. 2001).

Asynchronous discussion forums can mediate online discussions between students. However, discussion forums are predominantly shared community spaces in which individual voices are heard but are without a distinct identity (Duffy and Bruns 2006). Blogging provides a platform that promotes individual expression, enables students to establish their own "voice," and yields a richer conversational interactivity within a community (Wise 2005; Williams and Jacobs 2004).

Participants

The co-blogging class (CS111) had nine students co-blog on the same wiki blog-o-sphere. The class was composed of six graduate and three undergraduate students. The graduate students were all from Computer Science and the majority of the undergraduates were Computer Science majors or minors.

No formal evaluations were conducted to assess the students' *computer literacy* or prior *domain knowledge,* as no prerequisites of that nature were required for enrolling in the course. The majority of the students, particularly those from Computer Science, had already had some experiences with working with wikis.

Procedure

At the beginning of the semester, the students were trained in using a course website constructed using the WDP. This "tour" enabled students to practice using the various features of the WDP and writing wiki pages.

Prior to starting their co-blogging work the teaching assistant provided an in-class tour of the blog wiki. The tour showed the students how the blog wiki was organized differently, how they could find new contributions (blog posts and comments), and how they could use WikiStickies to write comments. The students also completed an exercise that had them use all of the blog wiki's features.

The blogging exercise lasted 4 1/2 weeks. Students worked intermittently throughout the week. The students were required to write at least two blog posts per week and one comment on a blog post by another student. The blogging work was primarily done outside of class. Early on, in an effort to help students become "fluent" using the technology and get into the routine of blogging, some time was set aside during lectures to allow students to ask questions and get feedback on their blogging work.

Metrics

We used several counting metrics to evaluate how interactive the students were in the co-blogging environment. By counting "reading events," it is possible to see how often a blog or blog post was read, by who, and how many times. By counting edit events, it is possible to tally conversations and explore features of conversations. Who participated in the conversation? Whose blog posts initiated the conversation? How many students participated in the conversation? How extensive was the conversation? Each measure tells a story about how interactive the students were.

To measure the extent of the conversing interactions, we explored the students' *conversations* and, in particular, their *contributions* to these conversations:

> *Conversation:* An ongoing discussion between two or more students that emerges as students write comments to each other centered on a particular blog post.

> *Contribution:* A blog post that starts a conversation or a comment made to a conversation. The blog post or comment becomes a contribution when acknowledged by other students (by reading or adding further comments).

Figure 9 shows an extensive conversation on the CS111 co-blog wiki that received multiple contributions from different students.

In the conversation in Fig. 9, Kate has written a blog post on the topic of "division of labor." Immediately below Kate's post, Steve comments and provides his perspective on the issue followed by a comment from Anne that is directed at both Kate and Steve. Then, Kate answers both Steve and Anne and asks them a question hoping to further the discussion. Finally a fourth student, Bob, adds a comment with his insights where he at first agrees with most of the points raised by Kate, Steve, and Anne but mentions other issues that might warrant further discussion.

When Steve reads Kate's blog post, then Kate has made a contribution to a conversation between the two of them; she does not contribute to a conversation if nobody reads her post. If Steve responds to Kate's contribution by posting a comment that Kate subsequently reads and/or comments on, then Steve has made a second contribution to the conversation started by Kate's blog post and so on. For example, assuming that someone read Bob's comment then the conversation would have a total of 5 contributions and 4 participants.

Did each blog have an audience?

The data in Table 7 shows that every student blog attracted a significant amount of attention. All blogs were regularly read and received comments from many students. Not all blog posts on a given blog were read by everyone. Although there was some overlap, the students did not always read or comment on the same blog posts. Students were active at different parts of the blog-o-sphere but each blog post regularly attracted readers.

On average, 6.8 different students read each of the student blogs (see line 1; each blog had 8 potential readers) and each blog was read on average 65.1 times.

Per week, each student read on average 9.9 blog posts (see line 5) but some posts they read more than once. On average, each student read 7.3 unique blog posts per week. The transcripts showed that students were cycling through other students' blog posts multiple times before writing their own. This is evidence that students were influenced and

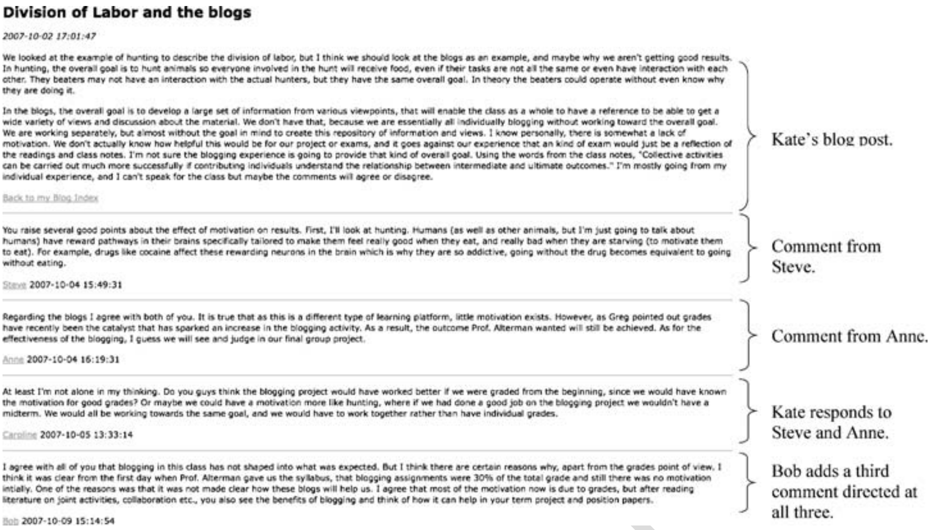


Fig. 9 An excerpt from an extensive conversation on the topic of "division of labor"

responsive to comments by other students; the co-blogging assignment was collaborative. Only 9% of the blog posts were never read by anybody (line 7). Seventy-seven percent of the blog posts were read by three or more students (sum lines 10 and 11) in addition to the blog post author.

The blogs also received a lot of comments. Eighty-nine percent of the blogs drew comments (line 12): 9.4 per blog, about two per week. Forty-five percent of the comments were read by at least 2 students other than the student who wrote the comment (sum of lines 16 through 18). Of the 26 comments not read by anyone, 22 were posted on or after the last 2 days of the blogging exercise. At this time, students were preparing for their term projects and were no longer required to co-blog.

Counting contributions to conversations

Ideally, students who are co-blogging about the course material not only read each other's blog posts but they engage in extended conversations by reading and contributing to any number of conversations.

The data in Table 8 shows that the students did converse during the online co-blog exercise. There were a large number of conversations where at least two students provided contributions — the students actually engaged in a dialog about the course material. Another interesting finding is that the students also read ongoing discussions between other students even if they did not directly contribute to the conversation: These students were essentially "witnesses" of conversations going on between other students. This was in part interesting because the students co-blogged within the same wiki. Thus, the shear size of the blog-o-sphere search space can make the discovery of "interesting conversations" more difficult.

To determine the total number of conversations of any length (number of contributions), we did a simple count. The situation is slightly different for determining how many students "witness" a conversation of a particular length. Any given student can witness more than one conversation. We counted how many unique student witnesses there were for each

Table 7 Did each blog have an audience?

Line	Metric	CS111
Blogs (each student had a blog)		
1	Avg. no. of students who read each blog	6.8
2	Fewest no. of students who read any one blog	4
3	Avg. no. of times each blog was read	65.1
4	Fewest no. of times a blog was read	14
Blog posts (each blog composed of multiple posts)		
5	Avg. no. of times a student read blog posts per week	9.9
6	Avg. no. of blog posts read by a student per week	7.3
7	% blog posts not read	9%
8	% blog posts read by only 1 student (other than the author)	11%
9	% blog posts read by only 2 students (other than the author)	3%
10	% blog posts read by only 3 students (other than the author)	23%
11	% blog posts read by more than 3 students (other than the author)	54%
Comments (each blog post can receive multiple comments)		
12	% of blogs that drew comments	89%
13	Avg. no. of comments per blog	9.4
14	% comments not read	31%
15	% comments read by only 1 student (other than the author)	24%
16	% comments read by only 2 students (other than the author)	18%
17	% comments read by only 3 students (other than the author)	15%
18	% comments read by more than 3 students (other than the author)	12%

conversation, grouped the conversations by length and then averaged the number of witnesses across conversations in each length group.

The students engaged in a total of 94 conversations, 38 of which had at least two contributions from two different students (the blog post author is always the first contributor). Sixty-three percent of the conversations with two or more contributions were witnessed by other students. For example, conversations with two contributions had on average 2.7 additional witnesses. In other words, these conversations had on average 4.7 participants (about half the class) engaged in some way in the discussion.

Table 8 Conversations on the CS111 blog wiki

Metric	CS111
Total no. conversations	94
Total no. conversations with 2 contributions	10
Total no. conversations with 3 contributions	15
Total no. conversations with more than 3 contributions	13
% conversations with 2 or more contributions read by “witnesses”	63%
Avg. no. “witnesses” in a conversation with 2 contributions	2.7
Avg. no. “witnesses” in a conversation with 3 contributions	1.9
Avg. no. “witnesses” in a conversation with 4 or more contributions	2.2

Discussion

The two case studies varied in how tightly or loosely coupled the students' collaboration was. In the tightly coupled case, the evidence showed that the students successfully worked online within a joint problem space. The students jointly focused on the important design tasks, and the relevant wiki pages received multiple edits from multiple students. The important tasks of the design activity were part of the scaffolding provided in the prefabricated wiki environment and functioned as coordinating representations. The data also showed that the larger teams were more likely to work online.

In the loosely coupled case, the analysis was somewhat different. The results showed that all student blogs had an audience, but not everybody read all the blogs or blog posts. A significant number of lengthy conversations emerged. Close to two thirds of conversations of length two or greater were read by students who were not direct contributors. Students found blog posts and comments to read, and conversations in which to participate. There was significant overlap in what the students read and discussed, but not everybody was active in the same "parts" of the blog-o-sphere.

In this section, we will quantify some distinguishing characteristics for these two different kinds of collaborative activities. The team design project course will be referred to as "tightly coupled" and the co-blogging course as "loosely coupled." Our expectations concerning how the two activities differ can be summarized as follows.

A tightly coupled team of students shares a joint focus. In the loosely coupled case, the class' interests are less focused. For a tightly coupled online activity, new events in the online workspace are more likely to be read by all team members. The "response time," the time it takes at least one student to read any new event, should be relatively short in the tightly coupled case. It is also more likely that a high percentage of events trigger direct responses in a timelier fashion in the tightly coupled activity. Finally, awareness mechanisms are likely to be used more frequently in the tightly coupled case because they help the student teams to jointly stay "on top of things."

In the tightly coupled collaborations, 95% of the contributions, whether original contributions or responses to previous ones, were read by *at least one* student other than the author of the contribution (see Table 9). In the loosely coupled activity, 92% of the blog posts, but only 69% of the comments, were read by at least one student other than the contribution's author. In the tightly coupled collaborations, 82% of the contributions were read by *all* the students of a given team. This is significantly higher than on the loosely coupled blog-o-sphere where only 0.01% of the contributions were read by *all* students. A chi-square test of independence compared the frequency (number) of contributions *read by*

Table 9 Coverage of contributions in the tightly and loosely coupled collaborations

Metric	Tightly coupled	Loosely coupled		Chi-square test of independence
% contributions read by at least one student	95%	79%	(92% blog posts) (69% comments)	$c^2(1, N=941)=43.52$, $p<.001$
% contributions read by all students	82%	0.01%	(2% blog posts) (0% comments)	$c^2(1, N=941)=374.02$, $p<.001$

Table 10 Responsiveness in terms of time in both the tightly and loosely coupled collaborations

Metric	Tightly coupled	Loosely coupled	Chi-square test of independence
% contributions read≤12 hours	76%	45%	$c^2(1, N=814)=26.88, p<.001$
% contributions read≤24 hours	83%	59%	$c^2(1, N=812)=23.75, p<.001$
% contributions read≤48 hours	89%	71%	$c^2(1, N=814)=16.04, p<.001$

at least one student and the frequency of contributions *read by all students,* and found the differences between the two activities to be statistically significant.

The tightly coupled students were timelier than the loosely coupled students in how quick *at least one other student* read new contributions (see Table 10). We used a chi-square test for independence to assess the significance of these differences. The results show that the frequency that a new contribution was read within 48 hours in the tightly coupled collaborations was significantly higher than in the loosely coupled activity. Response frequency beyond 48 hours was not significant.

A different measure of responsiveness counted the number of contributions in direct response to a previous contribution (see Table 11). For co-blogging, this occurs when either a blog post or comment receives a comment in response. In the tightly coupled activity, this occurs when a scaffolded wiki page previously edited by any one student is further edited by another student(s).

A chi-square test of independence compared the frequency of wiki page re-edits in the tightly coupled collaboration to the number of contributions made to conversations in the loosely coupled activity and found the difference to be statistically significant: $c^2(1, N=949)=14.45, p<.001$.

The tightly coupled students used the awareness mechanisms (either WikiEye or WikiNewsletter) more frequently to navigate the wiki than the loosely coupled students. This is not surprising because students participating in a tightly coupled collaborative learning assignment need to more closely monitor the online activity. On average, each student navigated the wiki 23.67 times using the awareness mechanism in the tightly coupled case compared to 9.67 times in the loosely coupled case. A t-test for independent samples confirmed the average differences as being statistically significant: $t(25)=2.67, p<.001$.

Concluding remarks

Using collaborative technology to extend the physical borders of the classroom can be of significant value. However, it does not guarantee that the students will either learn or "collaborate."

Table 11 Responsiveness in terms of contributions that are in direct response to other contributions in both the tightly and loosely coupled collaborations

Metric	Tightly coupled		Loosely coupled	
	%	Total	%	Total
% contributions that received direct responses	66	528	50	74

In a collaborative learning activity, students operate within an intersubjective space, which holds the activity together and makes it function effectively. When collaborating asynchronously online, students need to maintain some common view of their joint endeavor.

What makes for an intersubjective space that is sufficient for the collaborative task depends on the learning activity. Tightly coupled activities have different requirements for the "collaboration" than loosely coupled activities. If students participate in multiple different online collaborations within the same course, providing a common frame and style of interaction for each collaborative activity, has significant value because it significantly reduces overhead.

The wiki's style interaction has several properties that make it a productive framework for constructing different time and place collaborative learning applications. The technology is easy to use. Co-editing documents, and their automatic publication, are standard features of any wiki. The plasticity of wikis is conducive to customizing, preformating, or scaffolding the online interaction among the students. The malleability of wikis means teachers and students can further adapt the application after its initial deployment. The non-hierarchical control structure enables students to "own" and "control" their workspaces.

The WikiDesignPlatform (WDP) was developed to explore if the basic wiki, when coupled with additional components, can be used to custom-build learning applications. These applications supported a variety of functions, including class websites, collaborative workspaces, and prototyping environments.

Two case studies demonstrated the range of wiki-based learning activities. In the first study, students used a prefabricated WDP-based workspace to collaborate in a tightly coupled team design project. In the second case study, a loosely coupled learning activity, students used a wiki to co-blog on the course material.

In the tightly coupled collaborative activity, the evidence showed that the students operated within a joint problem space. The wiki scaffolding prefabricated by the teacher highlighted the design activity's most important tasks. The evidence showed that the students shared a joint focus on important material, and jointly problem solved on the important tasks. The wiki pages that represented these important tasks were edited multiple times by multiple students in each team. Another interesting finding was that as teams got larger they were more likely to use the wiki to coordinate and collaborate.

In the loosely coupled co-blog study, the evidence showed that all student blogs had an audience. Students found blog posts and comments to read, and conversations to participate in but not everyone was active on the same parts of the blog-o-sphere although there was some overlap. A substantial number of lengthy conversations emerged and a significant majority of conversations with two or more contributions were "followed" by students that did not directly contribute to the dialog.

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AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES.

Q1. The citation "Désilets et al. 2005" was changed to "Désilets and Paquet 2005". Please check if appropriate.

Q2. The citation "Boyd and Fales 1993" was changed to "Boyd and Fales 1983". Please check if appropriate.

Q3. Ref. [89] “Yukawa 2005” was not cited anywhere in the text. Please provide a citation. Alternatively, delete the item from the list.