Beyond Adoption to Invention:

Teacher-Created Collaborative Activities in Higher Education

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Submission to *Journal of the Learning Sciences*

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Abstract

The potential learning benefits of the Web are diminished due to the complexity of creating interactive, collaborative Web-based applications. The CoWeb is a collaborative website which allows users to create collaborative applications with great flexibility. The CoWeb facilitates *open authoring* where any user can edit any existing page or creating new pages. Using the CoWeb, both teachers and students have invented a wide variety of educational applications. Thus, the CoWeb serves as an example of an educational technology that has led to teacher inventiveness.

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I. Introduction: Supporting Open Authoring on the Web

There seems to be relatively little argument that the Web could have educational benefits. Creating Web pages can be a motivator for students due to the potential world wide audience that a Web page can reach (Blumenfeld et al., 1991). Web pages can offer user interaction, so that they are more than just passive conveyors of information. Combining the wide audience and interaction, it can enable collaboration (Guzdial et al., 1997) which can support complex and motivating student work (Blumenfeld et al., 1991) and the development of improved, shared conceptualizations (Jeong & Chi, 1997; Roschelle, 1992).

The technical aspects of making the Web *actually* work for learning are real challenges, leaving out for the moment the more enormous challenges of figuring out what to *do* with the Web to facilitate learning. The barriers to using the Web for educational applications are considerable. Using the Web requires mastery of concepts such as HTML, servers, FTP of files, and server-side scripting, client-side plugins, or Java applets for interactivity. While the potential to utilize the Web as a powerful medium for communication is real, the HTML language for creating these links and for formatting text

and graphics serves as a gatekeeper to prevent the least technical users from accessing the Web's potential. The interactive aspects of the Web are particularly complicated for teachers and students to access, requiring complicated programming of CGI scripts or Java applets. In short, the most powerful aspects of the Web also have the greatest barriers to students and teachers.

Where will Web-based educational applications come from? Literature from the computer-supported collaborative learning conferences suggests that it will be researchers and developers (e.g., Hall, 1997; Hoadley & Roschelle, 1999). Past experience in educational technology suggests that the source will not be the teachers—the early days of Basic and Logo showed that teachers are too time-constrained and lacking in technological training to build their own classroom technologies (Solomon, 1986). Research on facilitating adoption of collaborative practices suggests that teachers need a lot of help making the transition (Soloway, Krajcik, Blumenfeld, & Marx, 1996). Historical studies of higher-education teachers show that they are especially reticent to develop and apply innovations because the administrative and cultural barriers are so high (Cuban, 1999).

Surprisingly, we are finding exactly the opposite of this phenomenon occurring—university faculty at Georgia Tech (and elsewhere, but we are only studying Georgia Tech) are inventing their own Web-based collaborative activities that they are using in their own classrooms. This phenomenon is different than simply adopting the technology (e.g., Moore, 1995, Tyack & Cuban, 1995), but has moved beyond to

inventing new applications with the technology—applications that the developers had not considered.

We (the authors and our collaborators) have placed into classroom use a very simple forum for communication and collaboration called the *CoWeb*, for **Co**llaborative **Web**site. The CoWeb is not an advanced technology, and it does not support the creation of interactive elements the way that other tools do, e.g., AgentSheets (Repenning, 1994). Rather, the CoWeb supports a simple but powerful notion of *open authoring*. Any user can edit any page, and any user can create new pages, with links from and to any other page. There is no distinction enforced in the software between teachers and students, and there is no explicit scaffolding built into the tool to structure what students do, how they do it, or even how they learn with the space. On the other hand, what the CoWeb does do is to make it as easy as possible for teachers and students to create collaborative Web-based activities. For this one aspect of the Web, the CoWeb does resolve the issue of providing access with very few interface barriers.

We originally began exploring the CoWeb as an extension of our research on anchored discussion and collaboration (Guzdial, 1997; Guzdial & Turns, 2000). We had shown that collaboration spaces directly linked to media of interest to students (*anchors*) tended to create more sustained discussion than traditional classroom newsgroup discussions. But in our work, the anchors were always created by teachers. Was it the anchor, or the fact that the teacher said to go there? Could students create anchors? Through the CoWeb, we were able to explore how other students might discuss anchors created by peer students. While we found that students did use and explore peer-defined anchored collaboration

(Guzdial, 1999), that became almost peripheral to our discovery that teachers were actively and continually creating their own innovative applications.

Our finding is unusual in the Learning Sciences community. We are not reporting on an experiment, nor an invention. The concept of this kind of Web-based open authoring was developed by Ward Cunningham in his *WikiWikiWeb* (Cunningham & Leuf, 2001). Though we have created over a dozen iterations on our version of Cunningham's tool in the last three years to make it work better for classroom applications (Guzdial, Rick, Kerimbaev, 2001), the core ideas and features that are making it so successful in encouraging teacher innovation are not ours. Rather, we are reporting on a discovery—that the CoWeb is an example of a kind of application in which teachers actively invent their own uses. This is unusual, and we believe that studying the kinds of applications that teachers are inventing and the kinds of affordances that the CoWeb offers can help us understand how to better facilitate teacher inventiveness.

In the next section, the CoWeb is introduced. The following section lists several of the activities that have been implemented on the CoWeb at Georgia Tech. We have identified 25 kinds of activities that have been invented in the last three years of use. Many teachers tailor the basic forms for their own classes (Collaborative Software Lab, 2000). We highlight a handful of the activities here. Finally, we conclude with our observations and speculations on what is leading to this kind of teacher inventiveness.

II. CoWeb: Open Authoring on the Web

The basic idea behind the CoWeb is that any page is directly editable by any reader of that page and that any editor can create pages in the website. Ward Cunningham is the inventor of this kind of website, as implemented in his WikiWikiWeb[1]. The CoWeb was designed as a kind of WikiWikiWeb. The CoWeb is written in Squeak[2], a new and highly-portable form of the Smalltalk programming language (Ingalls, Kaehler, Maloney, Wallace, & Kay, 1997), so our version of the tool was originally called *Swiki* for Squeak-Wiki. The CoWeb is a more descriptive term of the end product, however, and has become the more common name.

The CoWeb is an open-source project, in that we make the CoWeb application and all of its development material available for any user[3]. The CoWeb has been adopted by other institutions, both academic and professional. While we have heard about similar invention at other sites, we focus here on the work of Georgia Tech teachers.

A CoWeb looks like a fairly traditional web site. Figure 1 is a screenshot of the front page of a CoWeb. A CoWeb page can have essentially any kind of media or formatting that any other Web page can. A key feature of a CoWeb page, however, is the link in the upper left corner of Figure 1, “Edit this Page.”

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[1] http://c2.com/cgi-bin/wiki

[2] http://www.squeak.org

[3] http://minnow.cc.gatech.edu/swiki

When the reader of the page seen in Figure 1 clicks “Edit this Page,” she gets a new page that looks like Figure 2. The text appearing in the scrollable text area is actually the text of the page in Figure 1. The reader can edit this text—perhaps correcting some of the text, adding new text, making a comment, or linking to other pages within the CoWeb or elsewhere on the Web. When the user clicks the “Save” button, the page will be updated to reflect the changed text.

While editing a CoWeb page, users can create new pages. The user types a title for the new page (e.g., “My New Page”) between asterisks (e.g., “*My New Page*”) in the text area. When the page is saved, the title text (without asterisks) becomes a link. Clicking on the link opens the new, blank page. The user can then edit the new page by choosing the “Edit this Page” link. The user never has to deal with creating files or making the files accessible by a Web server.

Editing a page is a simplified form of editing a traditional Web page.

- As can be seen in Figure 2, CoWeb pages can be written using the same editing conventions used in email. Text can be entered as paragraphs (with or without pressing the return key at the end of the line), and a blank line separates paragraphs.
- Links to existing CoWeb pages are entered the same as new pages, with the title between asterisks. For example, *Front Page* entered on a CoWeb page would create a link to the top of the CoWeb site.

- Links to external Web pages are entered as the URL between asterisks, e.g., *http://www.cc.gatech.edu*. When saved, the link becomes a hyperlink that will take the user to the page at the given URL address.
- Images can also be incorporated into a CoWeb page using the same technique as creating links. The user enters the URL for the image between asterisks (e.g., *http://myserver.edu/myimage.gif*). When the page is displayed, the image will be fetched and displayed in the place of the image URL on the page. Images can also be uploaded directly to the CoWeb through an Attachments page, and a simplified form of reference is supported (e.g., *+myimage.gif+*).
- If the user does know any HTML, it can be intermixed with CoWeb-style text. As the user learns more sophisticated HTML (e.g., tables and even JavaScript), these can be entered into the page as well.

The CoWeb provides supports that facilitate use of the site by users, all of which were originally invented in Cunningham's WikiWikiWeb.

- A “Recent Changes” page is available for every CoWeb. It lists each page by title in the CoWeb by the day on which it was changed in reverse chronological order (i.e., today is at the top). “Recent Changes” serves as an automatic table of contents for the CoWeb and as a mechanism to alert users when another user has changed an existing page or created a new page.

- The entire CoWeb is searchable from any page in the CoWeb. This enables users to find what others have done, even if long ago and far down the “Recent Changes” list.

The CoWeb offers only a little in the way of security. Each version of each page is saved, so it is possible to restore a page to any previous point of time. Pages can be locked to prevent editing by others, but in practice, very few pages are locked. The most powerful security measure on the CoWeb seems to be the power of social conventions. People do not normally destroy one another’s contributions. People generally identify themselves with their contributions. In our three years of use, with over 100 CoWebs, we have had only a couple incidents of malicious behavior, all quickly repaired. On the original Wiki by Ward Cunningham, users make sure that ideas are not lost—if someone inadvertently (or otherwise) deletes important text, “housekeepers” make sure that the text is repaired. In this way, even protection becomes a collaborative task (Cunningham, 1998).

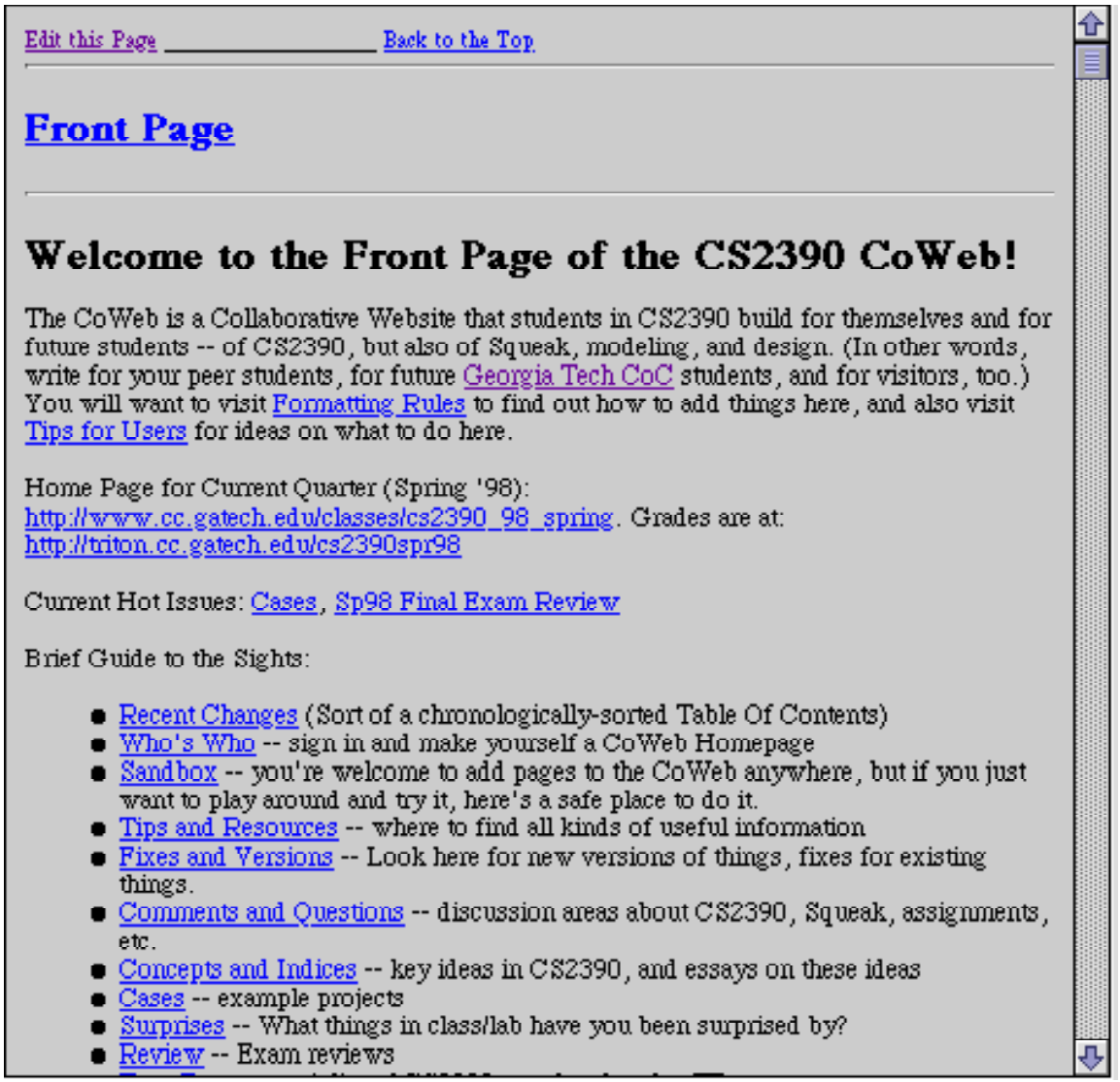

Figure 1: A Page in a CoWeb

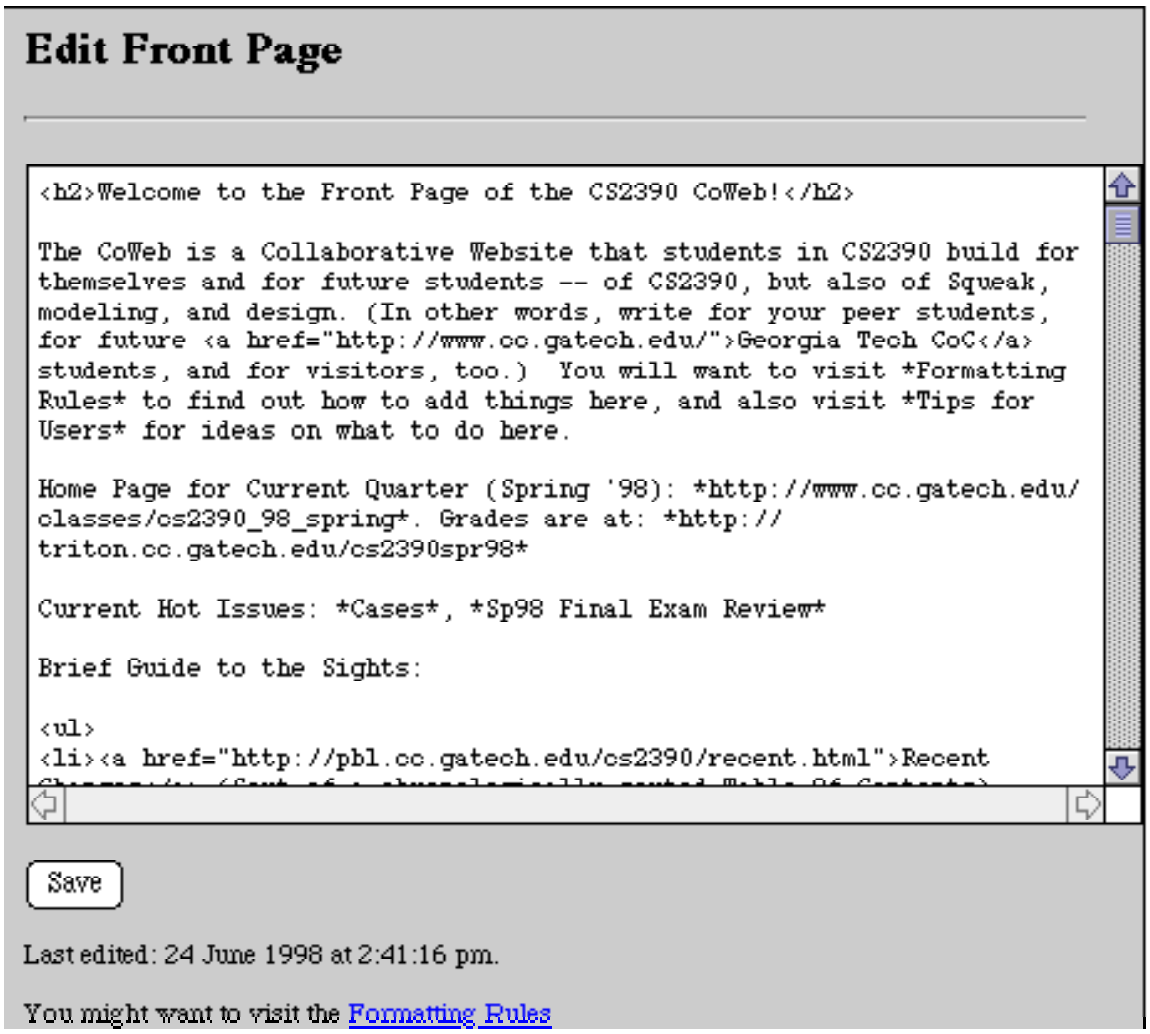

Figure 2: Editing the Page Seen in Figure 1

III. Uses of the CoWeb

We have three rough categories that we have been using to describe the kinds of activities that we see being invented for the CoWeb:

- *Distributing Information* activities uses the whole class as information gathererers and reporters, where the CoWeb becomes the storage place for the gathered information.

- *Collaborative Artifact Creation* activities use the whole class as co-designers and co-creators of one or more artifacts, where the CoWeb is either the vehicle for this creation or is a medium for supporting that creation.
- *Discussion and Review* activities use the whole class (and perhaps external visitors, as well) to discuss topics and review artifacts or ideas, where the CoWeb is the medium for this discussion and review.

A. Distributing Information

Information source. The first use of the CoWeb for many faculty is simply a course website. The CoWeb lends itself to being a course website particularly for those faculty who are uncomfortable with traditional methods of managing a website (e.g., creating and editing files). But even faculty who are comfortable with technical concepts like HTML and FTP appreciated the CoWeb as an information source, as one CS professor noted when he wrote me, "I just love this CoWeb! I just like the interaction that it enables. It's basically just a whiteboard that everyone can write on. Protections are always kind of a pain."

Most of these CoWebs, however, get expanded into collaborative information gathering. For example, several CoWebs host pages for movie, restaraunt, nightclub, and music reviews. The CoWeb becomes a public common ground where useful information can be noted and left for others.

Collaborative Hotlists. In several classes, the CoWeb is used as a collaborative bookmark or hotlist space. The teacher may create a top-level structure (e.g., “Links

about X" on one page, "Links about Y" on the other), but then the entire class finds information, posts links into these pages, and extends the structure with new pages for new kinds of bookmarks. If the CoWeb gets reused in multiple terms, the information gets expanded by future classes. The result is that the CoWeb becomes a useful resource for anyone on the topic of the class.

B. Collaborative Artifact Creation

Collaborative Writing. In a human anatomy class by Mindy Millard-Stafford, students were asked to do collaborative writing projects on the CoWeb. The teaching assistant created a page for each topic that groups could choose from. On each of the pages, the assistant created four or five spaces for signing up for the given topic. Students in a group would edit the same page to enter their text for the group project.

In another variation of this project, Millard-Stafford asked students to create a collaborative *glossary*. As she and the students found terms of interest in their readings, they were added to a CoWeb where the poster (and others) could provide definitions. In addition, links between related terms were easily added.

Cross-Class Projects. In one application of the CoWeb, the interaction of junior and senior students was the explicit goal. Two classes in Chemical Engineering were paired using the CoWeb. The Senior level course had students designing a chemical system then constructing a simulation of the system. The Sophomore level course was on analyzing exactly that kind of simulation. Because of curriculum paths, it was possible for the Seniors never to have taken the Sophomore level course. The two Chemical Engineering

faculty teaching the classes decided to require a cross-class project where Seniors would create the simulation, pass the data to the Sophomores who would analyze the simulation and return the results to the Seniors, who would use the results to complete the simulation. The CoWeb provided an open forum for sharing data, deciding on formats and other issues for such a technical collaboration, and working together on the solution.

Cross-Term Communication. Rather than start out with a blank space, teachers can reuse an existing CoWeb for the class (or teaching a related class). Since CoWeb pages cannot be deleted, the teacher would create new pages (e.g., "Old Front Page"), copy references to the past content into the new page, then restructure the CoWeb for his new class. In one case, the same CoWeb was used for the first and second courses in human-computer interaction. In another example, a CoWeb was used for both the graduate and undergraduate versions of the same class (in that order, so that graduate level discussions and examples were available in the space to the more novice students). In this activity, the artifact being collaboratively created is the CoWeb itself and the collaboration extends beyond class boundaries.

The result is a sense of "termlessness" (Koschmann, In Press) to the CoWeb and to the content of the course itself. The course is not limited to a single term, but extends across time. Student comments and server logging data indicate that students do visit the older content. Students see quite explicitly that the course domain extends beyond just this one course instantiation, and there are multiple ways to explore the domain. The older content serves as examples, even when not structured explicitly as cases. We hope

to explore in later studies exactly what students might be gaining from collaborative spaces that break down the perception of classes being limited to a single term.

Choose-Your-Path Adventure Game. In two class CoWebs, students created an adventure game about one of their assignments, as a Web-based "Choose Your Path" book. A student created a situation (in one class, based on the current assignment) with a set of links representing choices that the reader might select from. Other students added to the set of choices and created a variety of pages in the adventure game. In one class, almost three dozen pages were created in this adventure over a 48 hour period.

C. Discussion and Review

Anchored Discussion. One of common uses for collaboration spaces at Georgia Tech is *anchored discussion*. An anchored collaboration is a good structure to use for review activities, but is also useful for supporting focused discussions. Common examples of an anchored discussion are students studying for a final exam by posting and critiquing answers to sample questions, or students asking questions about an (anchor) assignment. Anchored collaboration was particularly simple to implement in the CoWeb, since the collaboration space can literally be the same space as the anchor. Anchored collaborations have been used in Architecture for debates (Craig, ul-Haq, Khan, Zimring, Kehoe, Rick, and Guzdial, 1999) , in Computer Science to discuss papers (Abowd et al., 1999), and in several disciplines to discuss homework.

Students did use the CoWeb for anchored, focused discussions. Students used a mechanism of writing their comments at the end of an anchor or comment page, usually signed. While there was no explicit support for tracking "threads" of comments (i.e., when one note comments upon another note, which comments upon another note (Guzdial, 1997)), a variety of mechanisms were invented by users (teacher or students) for marking threads.

Project case library. In some classes (e.g., CS, Mathematics, and Chemical Engineering), students were invited to post their homework assignments *after* grading, particularly if the grade was high. The CoWeb became a project case library for exemplary projects (Guzdial & Kehoe, 1998). Students used these projects as examples of high-scoring projects, as sources for ideas (particularly when two or more students posted their unique solutions to the same problem), and, in programming classes, as sources for code that could be re-used in new projects. Frequently, students were offered extra credit as an incentive to post to the project case library. The amount of extra credit was often linked to the amount of extra effort that the teacher felt that the student had put into creating the case. Simply posting what had been handed in for a grade was not worth as much as also including a discussion of the flaws and strengths of the project, for example.

In a class that the first author taught in computer science, the project case library became a mechanism for communication across classes. Guzdial used the same CoWeb for successive terms of the same class. Students in the second term using the CoWeb reviewed the project cases from the first term and left notes on them. Occasionally, students from the first term revisited the CoWeb during the second term, answering

questions and sometimes changing and improving their cases. As the project case library in this class grew larger (as of this writing, over 100 cases), some students began creating indices or recommendations of their favorite cases, also for extra credit. The CoWeb thus facilitated a kind of apprenticeship exchange, where more senior students came back to help younger students (Collins, Brown, & Newman, 1989).

Professional and Peer Design Review. Starting in Architecture, but now being copied in several classes, students are asked to post their work for others to review, sometimes peers, but sometimes experts from the outside. This kind of review can perform several roles. It can be a motivating activity that helps students view their work from a new perspective. It can be an activity that highlights a particular aspect of the students' work, e.g., when the teacher sets the ground rules about what's to be critiqued. It can be an activity that allows a large class to see what others are doing, in order to benchmark their own work.

We highlight one of these uses to provide more details. In one architecture class, students were asked to create CoWeb pages for each of their projects, in a space called CoOL Studio (Collaborative On-Line design Studio). CoOL Studio was designed and developed by Architecture colleagues David Craig, Saif-ul Haq, Sabir Kahn, and Craig Zimring. On one page, students were asked to post descriptions of their projects ("pin-ups") with scanned images of their drawings. On another page, students were asked to identify research questions that they needed to answer in order to complete their designs, such as the optimal size of hallways for a given kind of building and kind of use. The goal

of this structure was to provide students with an opportunity to review each others' projects and to help one another in answering their research questions.

On two occasions during the class, expert architects were invited to tour the students' pin-ups and comment on the projects. For each expert architect, a "tour page" was set up with the architect's name on it. The architect was invited to visit each of the pin-up pages listed on his or her tour, and comment on the pin-ups either directly on the student's page or on the tour page. This activity was judged to be fairly successful. The experts wrote a surprising amount of commentary. They wrote sometimes left comments on students' pin-up pages with particular advice, and sometimes they wrote on the tour page with general advice that the expert felt that the whole class group needed. Students took the reviews quite seriously, and the experts reported enjoying the experience (Zimring, Khan, Craig, Haq, & Guzdial, 1999). Experts particularly enjoyed reading one another's postings and seeing how their peers responded to the students' work.

Close Reading: In Composition classes, the CoWeb has been used to implement a form of "close reading" (Holloway-Attaway, 2001). The prose or poetry being studied is loaded into a CoWeb page, and students identify sections to discuss by placing asterisks around the phrase of interest. The asterisk-identified phrases get turned into links to page, where the section can then be discussed. Close reading is an activity that has often been used in these classes, but the teachers (especially Greg VanHoosier-Carey and Lissa Holloway-Attaway) used the CoWeb to make it a collaborative activity where students could see each others' annotations and expand on them. Holloway-Attaway has reported (2001) that she found the students' writing in the CoWeb to have higher quality than in

comparable classes because the students directly related their writing to the piece being reviewed. We are currently studying her hypothesis in a comparative study.

IV. Discussion: From Adoption to Invention

The CoWeb is a flexible tool, but that very flexibility may limit some of its applicability, as described further in the next section. The point of the previous section is to show that the CoWeb seems well-suited to the diverse nature of higher-education. Activities using the CoWeb have been invented and tailored by a fairly large number of teachers. We have only started to gather data suggesting that some of these activities have been *effective* in supporting student learning (e.g., Craig et al., 2000; Holloway-Attaway, 2001). We believe that they *can* be effective, when adequately integrated into a classroom, as described in the final section below where we consider why the CoWeb has been successful in encouraging invention by its users.

A. CoWeb Tradeoffs

The CoWeb is only one of several Web-based collaboration tools that have been created for learners. It is worthwhile looking at the tradeoffs that were chosen between others and the CoWeb, and to see how those tradeoffs impact the kinds of applications that can be authored with these tools. In general, the CoWeb does not structure the process of collaborating as other tools do, which makes it desirable in some settings (e.g., with adult learners) and less desirable in others.

CoNote (Davis & Huttenlocher, 1995), SpeakEasy/MFK (Hsi & Hoadley, 1994; Hsi & Hoadley, 1997), and CaMILE (Guzdial et al., 1997; Guzdial et al., 1996; Guzdial,

Turns, Rappin, & Carlson, 1995) have all been used successfully in education contexts. CoNote is a system through which students make annotations to existing Web pages. SpeakEasy/MFK and CaMILE are both threaded discussion spaces. SpeakEasy/MFK is a multi-representation tool where students are asked to make a statement about a discussion question, and then engage in a facilitated discussion about the question. CaMILE only offers facilitated threaded discussions, but it supports anchored collaboration so that threads of discussion can be accessed from any page on the Web. Both SpeakEasy/MFK and CaMILE offer a form of discussion facilitation where users are prompted to identify the kind of note that they are posting, as a way of encouraging reflection about the collaboration process.

These other collaboration spaces are perhaps better suited where the users need a more focused and more constrained activity, such as elementary school or middle school students. All three of these tools provide more support than the CoWeb. Students do not need to know anything about URL's, page editing vs. page viewing, or HTML. Usage in these other tools is more controlled. Users of CoNote, SpeakEasy/MFK, and CaMILE have to sign in, so that their identity is known and each user's contribution can be tracked. Users cannot delete or modify other users' postings. The CoWeb offers none of these features: It is more complicated to use, individual contributions cannot be identified with certainty, and it is possible for one user to modify or delete another user's posting.

On the other hand, the CoWeb has a higher "ceiling" than threaded discussion spaces. It is not possible in these spaces to have persistent, user-created pages for collaborative glossaries, nor is it possible for students to invent the activity of a collaborative adventure

game. The CoWeb provides more flexibility in authoring activities, but at a cost in cognitive load that may make it more suited to the adult learner—at least, without external support.

B. Supporting Teacher Inventiveness

Why are teachers inventing these kinds of activities with the CoWeb? What is it about the CoWeb that facilitates this kind of inventiveness? We are exploring these questions (through interviews, cataloging the activities, and studying the inventions), and we have a few suggestions.

Certainly, the CoWeb's simple interface leads to it being used. It also helps that we have been responsive in requests for new features (Guzdial, Rick, & Kerimbaev, 2001). Further, it seems to mesh with teachers' metaphors and understandings, e.g., the quote earlier about the CoWeb being "just a whiteboard that everyone can write on." However, there are lots of tools with good user interfaces out there, and not all of them lead to teacher invention.

Perhaps the most important factor leading to the invention we're seeing is that we had excellent early adopters. Success breeds success. When we had the CoWeb ready to test, we contacted a group of teachers who were already experimenting with educational technology. They did some things that led to early successes:

- The CoWeb was *integrated* into their classes. Students grades were linked to its use. Teachers talked about and encouraged its use. The CoWeb wasn't created and then left for anyone to pick up if they wanted it.

- The teachers themselves were already innovators. They were open to try things, and they had some technological skill to fall back on.
- The teachers created a path for students to become familiar with the CoWeb and then run with. All the successful uses involved some small, required activity, and then some interesting activities that engendered students' interest. Then the students, too, became agents of adoption and invention.

The early adopters, and those that came after, were interested in the CoWeb in part because of social pressure. The Web is everywhere these days. The expectations for the Web to be useful for learning are enormous, perhaps larger than any other media introduction since the computer. Large numbers of tools that have emerged for using the Web in classes (higher-ed, as well as K-12). Teachers feel this pressure (from students, parents, administrators, mass media, and so on), and are looking for ways to meet these demands. The CoWeb provides an easy way for teachers to explore collaborative Web-based applications in their classes—where it's easy to tune applications to the particular needs of the teacher and classroom. There's nothing about the CoWeb that induces inventiveness. Our experience suggests that an easy to use tool, that meets particular teachers' needs and demands (such as ease of integration with one's class), *can* lead to the kind of inventiveness that we're observing.

Acknowledgements

We owe many people thanks for their efforts in creating the CoWeb, its application, and our growing understanding of it. The CoWeb would not have happened without the

pioneering work of Ward Cunningham. The CoWeb was originally built upon the Pluggable WebServer , which built upon the work of Georg Gollman. All of the work in Squeak owes thanks to the “Squeak Central” team: Alan Kay, Dan Ingalls, John Maloney, Ted Kaehler, Scott Wallace, Andreas Raab, and Kim Rose. Our thanks, too, go to our initial users and collaborators: David Craig, Sabir Khan, Pete Ludovice, Mindy Millard-Stafford, Tom Morley, Matthew Realff, and Craig Zimring. The current version of the CoWeb is written by Jochen Rick (on top the Comanche webserver by Bolot Kerimbaev) with additions from Bert Freudenberg, Ted Kaehler, Lex Spoon, Stephen Pair, John McIntosh, Bijan Parsia, and Ross Philipson, among others. Janet Kolodner and Jennifer Turns have helped us in understanding what has been happening in the CoWebs, as well as Amy Bruckman, Noel Rappin, Colleen Kehoe, and Nora Sabelli. Funding for portions of this work has come from National Science Foundation grants RED-955045 and REC-9814770, the Georgia Tech “Al West” Fund, the Mellon Foundation, Siemens, Sun Microsystems, and Viant. Our thanks to reviewers of previous drafts, especially Jeremy Roschelle, Ben Bell, and Mimi Recker.

References

Abowd, G., Atkeson, C. G., Brotherton, J. A., Enqvist, T., Gully, P. A., & Lemon, J. (1998). Investigating the capture, integration, and access problem of ubiquitous computing in an educational setting, *Proceedings of CHI'98* . New York: ACM.

Abowd, G., Pimentel, M. d. G., Kerimbaev, B., Ishiguro, Y., & Guzdial, M. (1999). Anchoring discussions in lecture: An approach to collaboratively extending classroom digital media, *Proceedings of CSCL'99* . Palo Alto, CA.

Bruckman, A. (1997). The Design of Thoughtful Virtual Communities : Talk presented at Georgia Tech's College of Computing.

Collaborative Software Lab (Guzdial, Kehoe, Realff, Morley, Ludovice, et al.). (2000). *A Catalog of CoWeb Uses* (Georgia Tech GVU Center Technical Report GIT-GVU-00-19). Atlanta, Georgia.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, Learning, and Instruction: Essays in Honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum and Associates.

Craig, D., ul-Haq, S., Khan, S., Zimring, C., Kehoe, C., Rick, J., & Guzdial, M. (2000). *Using an unstructured collaboration tool to support peer interaction in large college classes.* Paper presented at the International Conference of the Learning Sciences 2000, Ann Arbor, MI.

Cuban, L. (1999). *How the Scholars Trumped the Teachers*. New York: Teachers College Press.

Cunningham, W. (1998). What gets protected in a (S)Wiki : http://pbl.cc.gatech.edu/myswiki/7.

Cunningham, W., & Leuf, B. (2001). *The Wiki Way*. Reading, MA: Addison-Wesley.

Davis, J. R., & Huttenlocher, D. P. (1995). Shared Annotation for Cooperative Learning. In J. L. Schnase & E. L. Cunnius (Eds.), *CSCL'95 Proceedings* (pp. 84-88). Bloomington, IN: Lawrence Erlbaum and Associates.

Guzdial, M. (1995). Software-realized scaffolding to facilitate programming for science learning. *Interactive Learning Environments, 4*(1), 1-44.

Guzdial, M. (1997). Information ecology of collaborations in educational settings: Influence of tool. In R. Hall, N. Miyake, & N. Enyedy (Eds.), *Proceedings of Computer-Supported Collaborative Learning'97* (pp. 83-90). Toronto, Ontario, Canada.

Guzdial, M. (1999). Teacher and Student Authoring on the Web for Shifting Agency : Presented at the Annual Meeting of the American Educational Research Association as part of the session *How can CSCL (Computer Supported Collaborative Learning) change classroom culture and patterns of interaction among participants?*

Guzdial, M., & Kehoe, C. (1998). Apprenticeship-based learning environments: A principled approach to providing software-realized scaffolding through hypermedia. *Journal of Interactive Learning Research, 9*(3/4).

Guzdial, M., Kolodner, J. L., Hmelo, C., Narayanan, H., Carlson, D., Rappin, N., Hübscher, R., Turns, J., & Newstetter, W. (1996). Computer support for learning through complex problem-solving. *Communications of the ACM, 39*(4), 43-45.

Guzdial, M., Realff, M., Ludovice, P., Morley, T., Kerce, C., Lyons, E., & Sukel, K. (1999). Using a CSCL-driven shft in agency to undertake educational reform, *Proceedings of CSCL'99* . Palo Alto, CA.

Guzdial, M., Rick, J., & Kerimbaev, B. (2000). Recognizing and Supporting Roles in CSCW, *Proceedings of CSCW'2000* (pp. 261-268).

Guzdial, M., Turns, J., Rappin, N., & Carlson, D. (1995). Collaborative support for learning in complex domains. In J. L. Schnase & E. L. Cunnius (Eds.), *Computer Support for Collaborative Learning (CSCL '95)* (pp. 157-160). Bloomington, IN: Lawrence Erlbaum Associates.

Guzdial, M., & Turns, J. (2000). Effective discussion through a computer-mediated anchored forum. *Journal of the Learning Sciences, 9*(4), 437-470.

Hall, R. (Ed.). (1997). *Computer-Supported Collaborative Learning Conference Proceedings*. Toronto, Ontario, Canada.

Holloway-Attaway, L. (2001). CoWeb/Collab: Collaboration and Community in Technology-Infused Writing Curricula : Conference on College Composition and Communication.

Hoadley, C., & Roschelle, J. (Eds.). (1999). *Computer Support for Collaborative Learning 1999 Conference Proceedings*. Palo Alto, CA: Unext.com, Stanford University.

Hsi, S., & Hoadley, C. M. (1994). An interactive multimedia kiosk as a tool for collaborative discourse, reflection, and assessment : Draft.

Hsi, S., & Hoadley, C. M. (1997). Productive discussion in science: Gender equity through electronic discourse. *Journal of Science Education and Technology, 6*(1), 23-36.

Ingalls, D., Kaehler, T., Maloney, J., Wallace, S., & Kay, A. (1997). Back to the Future: The Story of Squeak, A Practical Smalltalk Written in Itself, *OOPSLA'97 Conference Proceedings* (pp. 318-326). Atlanta, GA: ACM.

Jeong, H., & Chi, M. T. H. (1997). Construction of shared knowledge during collaborative learning. In R. Hall, N. Miyake, & N. Enyedy (Eds.), *Proceedings of Computer-Supported Collaborative Learning'97* (pp. 124-128). Toronto, Ontario, Canada.

Koschmann, T. (In Press). Tools of termlessness. In T. O'Shea (Ed.), *Virtual learning environments* .

Moore, G. A. (1995). *Inside the Tornado*. New York: HarperBusiness.

Repenning, A. (1994). Programmable subsrates to create interactive learning environments. *Journal of Interactive Learning Environments, 4*, 45-74.

Roschelle, J. (1992). Learning by Collaborating: Convergent Conceptual Change. *Journal of the Learning Sciences, 2*(3), 235-276.

Solomon, C. (1986). *Computer environments for children: A reflection on theories of learning and education*. Cambridge, Mass.: The MIT Press.

Soloway, E., Krajcik, J. S., Blumenfeld, P., & Marx, R. (1996). Technological support for teachers transitioning to project-based science practices. In T. Koschmann (Ed.), *CSCL: Theory and Practices of an Emerging Paradigm* (pp. 269-305). Hillsdale, NJ: Lawrence Erlbaum and Associates.

Turns, J., Guzdial, M., Mistree, F., Allen, J. K., & Rosen, D. (1995). I wish I had understood this at the beginning: Dilemmas in research, teaching, and the introduction of technology in engineering design courses, *Proceedings of the Frontiers in Education Conference* . Atlanta, GA.

Tyack, D., & Cuban, L. (1995). *Tinkering toward Utopia: A century of public school reform*. Cambridge, MA: Harvard University Press.

Zimring, C., Khan, S., Craig, D., Haq, S.-u. -., & Guzdial, M. (1999). *CoOL Studio: Using simple tools to expand the discursive space of the design studio.* Paper presented at the Design Thinking Research Symposium, MIT, Cambridge, MA.