Final Project Report on Integrating Learning Across Undergraduate Engineering Curriculum through Technology Supported Collaboration NSF Grant #REC-9814770

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Contents

1 Participants

Name	*Demographic*	*Role*
Mark Guzdial	Caucasian male	Associate Professor, co-PI
Matthew Realff	Caucasian male	Associate Professor, co-PI
Pete Ludovice	Caucasian male	Associate Professor, co-PI
Tom Morley	Caucasian male	Professor, co-PI
Kathering "Kayt" Sukel	Caucasian female	CS Ph.D. graduate student research assistant (GSRA)–worked on assessment of integrative understanding
Rodney Walker	African-American male	CS Ph.D. GSRA–worked on building CoWeb materials to support computer modeling learning
Clayton Kerce	Caucasian male	Mathematics Ph.D. GSRA–worked on cases to help students understand mathematics in computer modeling.
Eric Lyons	Caucasian male	Chemical Engineering Ph.D. GSRA–worked on cases to help students understand chemical engineering in computer modeling.
Jochen Rick	Caucasian male	CS Ph.D. GSRA–developed current version of collaboration software.
Bolot Kerimbaev	Asian male	CS Ph.D. GSRA–developed software to support sharing of MATLAB files in our collaboration spaces.
Stephen "Lex" Spoon	Caucasian male	CS Ph.D. GSRA–developed software to explore higher-bandwidth communication as a way of facilitating collaboration.
Joshua Gargus	Caucasian male	CS Ph.D. GSRA–developed an equation editor to ease communication and facilitate collaboration.
Karen Carroll	Caucasian female	CS M.S. GSRA–worked on assessment of collaboration and collaborative learning.
Michael Manning	Caucasian male	Undergraduate/graduate student in Industrial and Systems Engineering(ISyE). Worked on collaborative web site to promote mathematics learning.
Devon Dickerson	African-American male	Undergraduate student in Industrial and Systems Engineering. Worked on collaborative web site to promote learning in mathematics courses aimed at ISyE students.
Andrea Forte	Caucasian female	CS Ph.D. GSRA–worked on assessment of student learning
Jason Ergle	Caucasian male	Undergraduate student research assistant (USRA)–worked on multimedia tools for CS learning.

During the scope of this grant, co-PI Guzdial received a grant from the Mellon Foundation on *Cost Effective Uses of the CoWeb Collaborative Learning Technology to Improve Higher Education.* This project led to a collaboration with Lissa Holloway-Attaway of Georgia Tech's School of Literature, Culture, and Communication (LCC). The combination of the two grants supported some of the most significant findings from this project.

We received a grant from Sun Microsystems for more powerful servers to support our project.

2 Activities and Findings

The major contributions and findings of this project are:

- The establishment of the CoWeb (Collaborative Website, also known as *Swiki*) as one of the more significant collaboration tools used in higher education. A search today for "Swiki" on `http://www.google.com` returns 139,000 hits. A review of the first couple hundred of these hits shows that the vast majority of hits being use of our software (available at `http://www.swiki.org`). American schools using CoWebs to support teaching and research including University of Colorado at Boulder, Allegheny College, Lakota University, University of Kansas, and the National Center for Atmospheric Research. Uses of the CoWeb outside of the United States can be seen in domains .sk, .be, ch., .jp, .se, .fr, and .nz and include significant U.S. research collaborators such as ETH. Here are at Georgia Tech there are a dozen CoWeb servers now serving over a thousand students per term. *Every* Chemical Engineering course at Georgia Tech now has its own CoWeb.
- Careful documentation of the problems that prevent collaborative activities from taking root in technical courses. We have disseminated these results in several education and research communities, including Engineering Education [Guzdial et al., 2001a], Chemical Engineering Education [Realff et al., 2000], Mathematics Education [Morley et al., 2000, Morley et al., 2002], Computer Science [Guzdial et al., 2000], Learning Sciences [Guzdial et al., 2002], and even English Composition Education [Holloway-Attaway, 2001]. We have followed up these studies of students with a study of faculty attitudes towards improving the collaboration climate [Guzdial et al., 2002].
- At the same time, we have published results indicating the lack of integrative understanding that such collaboration could help address [Sukel et al., 2000].
- We have undertaken some more theoretical research to explain the phenomena of learning in Computer Supported Collaborative Learning that doesn't match the predictions of laboratory-based studies of how learning might arise from collaboration. Our findings suggest how student learning might arise even if there is no visible sign of collaboration in the computer support [Guzdial and Carroll, 2002].
- We have produced materials to support teachers who want to use the CoWeb in their courses. Our website `http://minnow.cc.gatech.edu/swiki` provides very easy to follow directions for downloading and starting the software. Our papers site (`http://coweb.cc.gatech.edu/csl/Papers`) includes *The CoWeb Catalog* with a couple dozen CoWeb-based collaborative activities for classrooms [Lab, 2000] and the *CoWeb Guide for Teachers.*
- With extension funding provided by CCLI, we have started an effort (based on our exploration of computer modeling) to develop a new approach to learning computer programming that we call *data-first.* We hosted a workshop to explore media manipulation in CS courses, as a form of data-first computing. We have influenced a new Engineering course using this approach, and have developed a new Computer Science course around this approach [Guzdial, 2003, Guzdial and Soloway, 2002].

2.1 Narrative Description of the Project and its Results

The initial focus of the proposal was to encourage integrative learning among Engineering students by encouraging collaboration around a common theme across disciplines. The theme we selected was *computer modeling.* We teach computer programming (including MATLAB) in Computer Science (and now, Engineering) freshmen courses, differential equations in Mathematics, and implementation of differential equations in programs to model Engineering problems in upper-division courses. The problem is that these classes are not at all integrated: Terms for the same things change between courses, problems used in earlier courses are not at all like those that students see in later courses, and the faculty don't communicate about these courses–faculty communication across disciplinary boundaries is quite uncommon [Cuban, 1999].

Our plan was to provide a collaboration space, the CoWeb (or Swiki), which was being used successfully in several other courses [Guzdial et al., 2001b]. The idea was to provide a place where students could go for help on any aspect of computer modeling, but since the space encouraged collaboration, the help might come from students in other disciplines taking other classes whose overlap might inform one another. For the Senior struggling to remember differential equations, the Sophomore taking it just then is the best help. For the Sophomore, the Senior's problems tell her what she has to look forward to.

The actual execution was much more disappointing. Students actively avoided our eforts.

- To encourage collaboration in the CoWeb, we created a mandatory assignment that required collaboration between a Chemical Engineering and a Mathematics course. The students in Chemical Engineering created simulations that generated data for the Mathematics students to analyze, and then provide the results back to the Chemical Engineers. 40% of the Mathematics students accepted a zero on the assignment rather than collaborate with the Chemical Engineers.
- One semester, we started using the CoWeb in an Freshman Architecture course ($n = 171$) at the same time that we started in a Senior Chemical Engineering course ($n = 24$). After ten weeks into the semester, the Architecture students had generated over 1500 pages, with some discussion pages having over 30 authors. In the Chemical Engineering course, not a single student had made a single posting yet. In another semester, in a Computer Science course of 340 students, only 22 students participated.
- We had a hypothesis that part of the inhibition to participate in the Engineering and Mathematics class was a technical one. The content of many of these courses involves equations, and equations are difficult to post on the Web. If students couldn't "talk" in the modalities that were the most comfortable for them, it would make sense that they would avoid our tool. So, we created an applet-like tool that allowed users to create equations by simply dragging and dropping components from pallettes, and then drop the equations into a bucket for rendering to a GIF format and for easy posting. We installed it in a CoWeb for a Mathematics class and for a Chemical Engineering class. Faculty used it and praised it. Not a single student even *tried* it in either class.

After two years and over a dozen relatively-unsuccessful attempts to get collaboration activities working in Engineering, some CS, and Mathematics courses, we shifted our focus from pushing the collaboration agenda to understanding why there was such resistance to it. We published our results in several venues [Guzdial et al., 2001a, Guzdial et al., 2002]. We found three main reasons for the lack of collaboration:

- *Rational response to competitive conditions*: If students perceived the course to be highly competitive, they often believed it to be graded on a curve–even if there was evidence to the contrary. When the course is graded on a curve, it's only rational to avoid collaboration.
- *Learned helplessness*: In several courses, students expected to do badly or expected to get little help, so *requesting* such help (in a collaborative, public setting) was to label oneself and would probably not result in any help.
- *A lack of models*: Students don't see faculty collaborating across disciplinary boundaries. They don't know what to do, nor that it's valued.

In our last year of the project, we followed up on our study of student resistance to a study of faculty. After these studies, we realized that the best opportunity for change was to directly address the faculty who might be interested in using the CoWeb. In Spring 2001, we offered a workshop to Georgia Tech faculty who wanted to use the CoWeb. During a two-hour lunchtime session, we led a dozen faculty through using the CoWeb for themselves (each had their own station). We had three faculty talk about how they used it. We also offered the faculty support documentation, including a copy of the catalog of the activities that teachers had invented in their own courses [Lab, 2000]. At end of Summer 2001, we followed up with each of the faculty and offered them additional support, including offers to create and host CoWebs for them on our own servers.

In November 2001, we followed up with the faculty who took our workshop. Only one faculty member (from Psychology) had started using the CoWeb. The rest (including Mathematics and Engineering faculty) had not adopted it. We surveyed all of the faculty. The common explanation was a lack of time to explore new options in their classes.

Meanwhile, the School of Chemical Engineering decided in Fall 2002 to buy into the CoWeb experiment more deeply and have provided every course in the School with a CoWeb for the teacher and students' use. It's still not clear whether this use will actually result in more student collaboration nor more integrative activities, but we plan to study this effort to see how the culture evolves.

We also promised in our proposal to study how learning was arising in collaborative contexts. Learning science theories of how learning arises from collaboration requires extensive dialog [Roschelle, 1992]. However, empirical studies of computer-supported collaborative learning find much less dialog than the theories suggest. We published a paper [Guzdial and Carroll, 2002] showing that, even when we can demonstrate learning externally, not much dialog is measured in the tool. Through a set of interviews, we established that the computer support was serving as a *catalyst* for learning *outside* the computer support. In this way, we pave the way for a new theory of how learning is facilitated by computer-supported collaborative learning environments.

2.1.1 Data-First Computing

Through our work together over the three years of this project, the co-PI's on the project observed how computer modeling was taught and not learned in several disciplinary settings. We evolved a model (due mostly to Realff and Ludovice) of teaching programming that we call "Data-first computing." In professional practice, most users of computers don't seek to use the computer because they want to. They start out with some data that they need computation for, and then they (grudgingly) learn enough computation to solve their problem. Students are no different. We believe that we could better motivate students to learn programming if we focused on data of interest and the computation needed to analyze or manipulate that media.

Realff, Ludovice, and Morley developed a set of data-driven activities to use in a variety of Chemical Engineering and Mathematics courses, as well as in a new introductory course on programming taught in the College of Engineering. Our sense is that the pilot activities were successful, and we hope to continue that experiment.

We used the extension funding from CCLI in our final year to offer a workshop on integrating multimedia into CS courses, a data-first approach for computing. 54 attendees participated, including 26 computer science faculty from around the country. Presenters included Alan Kay ("Father of personal computing" and designer of the programming language Squeak which is being used for multimedia in CS education), John Maloney and Dan Ingalls from Disney, Jeff Pierce from CMU, and Rick Zaccone from Bucknell U. The workshop materials are available at `http://coweb.cc.gatech.edu/mmWorkshop`. The evaluation results were quite positive:

How successful was the workshop for you?

- Very successful. I got many useful ideas.
- Very good considering the compressed time frame. I have diverse interests in computing at the university and elementary levels, so this was a lot of fun for me.
- Very–many great contacts with both faculty and Squeakers. Lots of great demos, too.
- Very successful!! I learned a lot from the participants. I also met people that are doing cool things with Squeak.
- Extremely successful.

What did you expect from the workshop? Did you get out of the workshop what you wanted?

- Yes, I got more than I expected from the workshop.
- Make contacts with people for future ideas and help – yes.
- I wanted to understand the challenges and success paths that others have experienced, and that goal was met.
- A taste of where teaching related to Squeak is now. This was very much the topic, very helpful.
- Some ideas for using Squeak in non-majors courses. Yes, workshop was useful.
- I wanted to learn about problems in undergrad C.S. education, and I did.
- My objective was to see if Squeak could be used effectively in a CS-0 type of course. I believe it could, after seeing the workshop demosntrations and talking to participants.
- How to do some multimedia in beginning CS courses. I've got a good idea of how to begin.

A follow-on workshop was offered in Feburary at ACM SIGCSE 2003 with 14 faculty attending. Evaluation results on that workshop have not arrived yet.

2.2 Teaching and Research Activities Provided to Student Assistants

Our students were intensively involved in the assessment and writing efforts. Our students are frequently co-authors with us.

2.3 Outreach Activities

Our workshops, at Georgia Tech and at ACM SIGCSE, have been successful ways of reaching out to the external community. We have reached many other people with our open source software (at `http://minnow.cc.gatech.edu/swiki`), and the links from that website to our research findings and our teacher publications. The Google numbers attest to the impact that the software has had on the greater research and education community.

3 Publications and Products

Most of these papers are accessible from `http://coweb.cc.gatech.edu/csl/Papers` which is indexed by Google and other search engines.

- We presented our early attempts on using the CoWeb to instigate cross-disciplinary collaboration at a conference of mathematics teachers [Morley et al., 2000] and at a *Computer-supported collaborative learning* conference [Guzdial et al., 1999].
- Our first study and analysis explored just how integrated students' understanding of computer modeling was. Using isomorphic problems that had varying amounts of integration across programming, mathematics, and engineering application, we conducted a pilot study to demonstrate just how difficult students found to integrate their knowledge across these areas [Sukel et al., 2000].
- The *CoWeb Catalog* points to successful CoWeb-based collaborative learning activities that have been used by teachers (almost all invented by teachers outside of our project!) [Lab, 2000].
- In our exploration of factors that might attract more Engineering students, we developed a higher bandwidth version of the CoWeb, called *MuSwiki*. Lex Spoon developed the software and conducted a trial assessment [Spoon and Guzdial, 1999].
- In a significant journal publication, we presented the value of teacher-developed collaborative activities that we saw in CoWeb use [Guzdial et al., 2001b].
- Our design methodology for the CoWeb emphasized recognizing and supporting different roles in the collaborative enterprise. For example, the teacher of a course often *designs* activities for students, but a teaching assistant is often the *implementor* of these activities. Each need different software supports. This design process was documented in a *CSCW Conference* publication [Guzdial et al., 2000].
- Our most significant Engineering Education publication was our paper in *Computers and Chemical Engineering* on our attempts (and the need for) integrative learning [Realff et al., 2000].
- Our collaborator, Lissa Holoway-Attaway, presented the CoWeb and some of our results at the *Conference on College Composition and Communication* [Holloway-Attaway, 2001]. A few months later, at the Computers an Writing Conference, Lissa was awarded the McGraw Hill Award for Technology in Composition and Rhetoric for her innovative use of the CoWeb in English Composition classes.
- Our most significant work with collaborator Lissa Holloway-Attaway (with Jochen Rick and Karen Carroll from this project) was a controlled study demonstrating the learning benefit of a computer-supported collaborative activity as compared to a non-collaborative activity [Rick et al., 2002].
- We have published our findings on impediments to collaboration for students in highly-competitive classes in the *FIE* Engineering Education conference [Guzdial et al., 2001a], at a conference on e-technologies in Education Engineering [Ludovice et al., 2002], in the *Computer-Supported Collaborative Learning* conference (the latter, with our faculty study results) [Guzdial et al., 2002], and at a conference for collegiate mathematics teachers [Morley et al., 2002].
- Our work towards resolving the tension between empirical studies of CSCL and theoretical stances on collaborative learning was presented at *CSCL 2002* [Guzdial and Carroll, 2002].
- We published a paper in the *Communications of the ACM* about the need for a data-first approach (not called by that term at that name) to attract students being turned off to programming [Guzdial and Soloway, 2002]. Our first paper on a data-first oriented course will appear this summer [Guzdial, 2003].
- A new book in which we have a contributed chapter decided to include our system in its title: *From Usenet to CoWebs: Interacting with Virtual Communities and Information Spaces* [Dieberger and Guzdial, 2003].

4 Contributions

In summary, the major contributions and findings of this project are:

- The establishment of the CoWeb (Collaborative Website, also known as *Swiki*) as one of the more significant collaboration tools used in higher education. A search today for "Swiki" on `http://www.google.com` returns 139,000 hits, with the vast majority being use of our software (available at `http://www.swiki.org`).
- Careful documentation of the problems that prevent collaborative activities from taking root in technical courses.
- At the same time, we have published results indicating the lack of integrative understanding that such collaboration could help address[Sukel et al., 2000].
- We have undertaken some more theoretical research to explain the phenomena of learning in Computer Supported Collaborative Learning that doesn't match the predictions of laboratory-based studies of how learning might arise from collaboration.
- We have produced materials to support teachers who want to use the CoWeb in their courses. Our website `http://minnow.cc.gatech.edu/swiki` provides very easy to follow directions for downloading and starting the software. Our papers site (`http://coweb.cc.gatech.edu/csl/Papers`) includes *The CoWeb Catalog* with a couple dozen CoWeb-based collaborative activities for classrooms [Lab, 2000] and the *CoWeb Guide for Teachers*.
- With extension funding provided by CCLI, we have started an effort (based on our exploration of computer modeling) to develop a new approach to learning computer programming that we call *data-first*.

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