# Computer-Supported Collaborative Learning in Support of SMET Undergraduate Retention: A Practice-Oriented CSCL Research Agenda

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## Project Summary

Collaborative learning in general and Computer-Supported Collaborative Learning (CSCL) in particular can positively impact student learning. Several studies have shown significant impacts in SMET and other courses [25, 38, 45]. How it impacts student learning is still an open matter. We know that dialog has an impact on student learning [46, 28], but we know that that's not the only mechanism engendered by collaboration which impacts learning, and it may not even be a necessary one [18].

One way that collaboration seems to impact student learning is by sustaining student interest and motivation (to remain active within a class) which can result in improved retention. We have examples in the literature of collaborative learning situations dramatically impacting retention in a SMET course with historically low retention (e.g., [40, 17]). However, we know that, in very similar courses, collaboration can fail to have any impact at all [20].

We propose in this project to explore the ways in which CSCL can impact student interest and motivation as factors in retention in SMET courses. Our goal is to be able to make predictions about student retention based on classroom culture and CSCL practices. We then propose to directly apply the results by selecting courses with low retention and testing our predictions by attempting to improve retention by direct intervention in classroom practices and through implementation of CSCL-based activities. The broader impact is a deeper understanding of retention in SMET and developing a research agenda around directly applying learning science technologies toward classroom practice problems.

This work is in ROLE Quadrant Three, in that we are seeking to improve SMET learning by improving retention via a CSCL-based approach. The third year of the project, where we seek to change particular classes through our approach, will requirement development of a systemic approach to identifying and addressing retention problems, which starts moving the research into Quadrant Four.

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# Computer-Supported Collaborative Learning in Support of SMET Undergraduate Retention: A Practice-Oriented CSCL Research Agenda

## 1 Introduction: The potential of CSCL to impact SMET learning

Collaboration can be a significant factor in student learning. Through collaboration students can reach understandings that none of the collaborators held previously [46]. Through collaboration, students can learn how to collaborate better—a significant result in fields where professionals must collaborate, e.g., Engineering. Accreditation for Engineering curricula requires collaboration [1] both because of the belief that it aids in learning and because of the desire for students to learn about collaboration itself [3].

Computer-supported collaborative learning (CSCL) is promising for providing the benefits of collaboration in a form that can be more effectively instituted in a wide range of classrooms. Collaboration in its face-to-face form can be challenging to institute in classes [9]. Forming and maintaining groups, arranging for meeting times, or possibly using class time can be impediments to using collaborative learning opportunities. With CSCL, collaboration can be just-in-time or asynchronous, and much larger groups can participate without diminishing the learning opportunities [25].

What we are starting to learn is that collaboration can also influence retention. Besides the opportunities that it provides for learning, collaboration can influence factors that themselves are important for learning. In a couple of recent studies in computer science (one of which used CSCL), collaborative learning situations dramatically improved retention-students stuck with the class longer than students had in similar classes without retention, and (presumably) learned more than they would have had they dropped out.

Retention is a significant issue in science, math, engineering, and technology (SMET) education [51, 2, 24]. Among minority populations and women, high attrition rates exacerbate the problem of underrepresentation in many scientific and technical fields. [13, 14]. It's clear that we lose many students in the SMET educational pipeline. If we can influence retention positively, we can improve SMET education.

**The goal of the proposed project is to understand how CSCL can positively influence retention in SMET education, test our understanding, and then use this understanding to change classroom practice.** We believe that CSCL can be effective at improving retention and can be (relatively) easily instituted into classes. Our three year study will develop a theory for how CSCL influences retention in SMET classes, will test the theory by making predictions about classes and matching them to observed classes, and then going into SMET classes with low retention and attempt to change them through use of CSCL-based activities in order to improve retention.

This project is using a model for education and learning science research that's related to design experiments [5], but with different purposes. Much learning science research draws from psychology as its model-our goal is understanding of how learning takes place at the cognitive level. Our model in this research is more of an *engineering* model than a science model, and we think that's an important distinction. We have a desired end state, of a larger percentage of students remaining in classes while learning. The point of our research is to study and attempt to directly influence the factors that influence our end state (e.g., motivation and student interests). We expect to make contributions to understanding about the factors that we identify influencing retention, while we are attempting to directly change education practice and outcomes.

## 1.1 Where and How CSCL can Influence Retention

The literature on collaboration does provide strong examples of where collaboration has facilitated learning, e.g., Roschelle's study of learning physics collaboratively [46], or Jeong and Chi's study of students learning anatomy in a peer-learning setting [28], or the work on peer-tutoring [6]. Our definition of collaboration is where more than one student is interacting with other students with a goal of one or more of the students' learning.

Our most foundational work on the social aspects of learning suggests that *all* learning is social—that our internal mental dialog is developed by copying the external dialogs we have [8]. Much of our post-secondary education can be seen as a form of joining a community of practice and learning the social norms of that community [37]. We know that most undergraduate practice does not recognize the value of the social aspects of learning [21]. Fortunately, we don't need to change *all* of educational practice for our goal—rather, we can change culture subtly and introduce collaboration with little cost using technology support (CSCL), and thus gain some of the benefits of the social perspective on learning.

CSCL can be effective in facilitating learning in a collaborative setting . The earliest examples of CSCL showed marked improvement on standardized test scores [48, 49]. Later studies have shown that students have been facilitated in their learning by CSCL in physics [25], cognitive science [38], and, in our own work, English Composition [45]. CSCL-using students in our study performed better on a post-test than students not collaborating.

Our theory of how collaborative learning takes place says that much of the learning arises from the dialog between students [46, 28]. Through their discussions, students make hypotheses, test their hypotheses (often simply through the discussion), and reformulate their hypotheses [46]. However, CSCL practice suggests that other mechanisms are in play, too [18]. In actual practice, much less dialog is observed than our theory says is needed for learning to occur, yet we still do measure learning in CSCL classrooms.

It seems that CSCL plays more of a role in facilitating learning than simply providing an opportunity for dialog. In CSCL, the dialog is visible and persistent. Students can come back to a discussion later, look at what others have discussed, contextualize the dialog by connecting it to an artifact [23], search among discussions, and even continue discussions that seemed to have ended. In our interviews with students, we find that CSCL can play several roles in learning. For some students, it's a catalyst for individual learning, e.g., "I saw what was posted, and decided to go explore before posting anything." For others, it's a catalyst for impromptu face-to-face collaborations, e.g., "We discussed what we saw in the [collaborative Web space]."

As a way of facilitating more student participation (particularly in traditionally lecture-based courses), CSCL can provide distinct advantages over face-to-face collaboration not only for logistical reasons, but also because it encourages new patterns of interaction [25]. We know that student-instructor and student-student interaction changes considerably when it moves from the classroom to the chatroom. Discussion shifts from primarily teacher-initiated to student-initiated [27].

The use of CSCL in Architecture is a useful case in point. Architecture is traditionally taught in small studios [50]. What goes on in the studio is the creation of a community of practice, artifact-centered dialog, and "collaboration-in-the-air" [31] where simply hearing others' dialog and seeing each others' work influences the learning. At Georgia Institute of Technology (Georgia Tech), one of the larger Engineering schools and technical institutes in the country, the introductory courses have over 150 students—far too large for a traditional studio. Through use of CSCL, much of the interaction, sharing, and artifact-focused collaboration was able to be replicated successfully in a large class setting [10].

In recent studies, we've also found that collaboration can be a factor in improving retention. Retention is not a cognitive construct, but a measurable outcome of other cognitive constructs such as student interest (if you're more interested in a topic, you'll more likely stay in class) and motivation (your desire to succeed in the class, sometimes despite interest [42]). Collaboration, even in a computer-supported version, has been shown to play a role in improving retention.

## 1.2 Improving Retention in SMET Classes with Collaboration

Two recent studies in computer science education research have highlighted the potential for collaboration to improve retention. The first used face-to-face collaboration, while the second used CSCL.

Pair programming is a relatively new practice developed in industry where pairs of programmers work together [54]. Pair programmers are strictly forbidden to use any program code that was written by either individual programmer. Instead, all code is written with one person typing and the other person observing-sometimes critiquing, sometimes making suggestions, sometimes just thinking it through with the programmer at the keyboard. Typically, the pairs switch roles regularly.

Researchers like Laurie Williams of North Carolina State University have been exploring the use of pair programming in introductory computer science. Introductory CS has historically low success rates—50% of the class withdrawing or failing is common [16, 47]. Williams and her colleagues have found that pair programming has not had significant influence on performance in introductory classes (e.g., the resultant code is not significantly better than individuals' code) though it has in other classes [53], nor has pair programming significantly improved learning as measured by post-test performance [40]. However, there has been a significant improvement in retention. Students in pair programming stick with the class more than students who do not. ***Allison or Andrea, please insert here some of her statistics about majors.***

The disadvantage to pair programming is that it's difficult to manage. What happens when one of the pair doesn't show for a session? Do you set up triplets or have the sole programmer work alone (potentially at a disadvantage)? How do you form pairs? How do you handle dysfunctional pairs? If CSCL in large groups could have similar effects, we could have the advantages of collaboration in improving retention without the cost of managing the groups.

We recently developed and evaluated a pilot introductory computer science course aimed particularly at non-majors [17], funded in part by NSF CCLI grant #0231176. The course *Introduction to Media Computation* emphasized the communications aspects of computation, by having students manipulate pictures, sounds, text, and movies as the context for their programming and learning. Collaboration played a significant role in the course. 121 students enrolled in the course, 2/3 women.

- Students were encouraged to collaborate on a subset of the homework assignments. These were not explicitly organized by the instructor and mostly occurred face-to-face. There were also pre-quiz activities that students worked on explicitly and collaboration was encouraged.
- The course also had its own *CoWeb* (Collaborative Webspace) [22] which was used extensively in the course. Students could ask questions and make comments about the course (sometimes anonymously). Students were encouraged to post the media resulting from their work to share in *Galleries*. Exam review questions were posted on the CoWeb with space created for questions, comments, and proposed solutions. The instructor would participate in the exam review to provide feedback on answers and help respond to questions. A *Soapbox* that appeared at the top of every page in the CoWeb website was student editable and thus served as a way to raise awareness in the student community.

The course had an 89% success rate—only 10.7% of the class withdrew (3 of 121 students, 2.5%) or received an F or D (10 of 121 students, 8.2%). In contrast, non-majors in a pair programming CS1 class had a 66% success rate [40]—which was still significantly better than non-majors in a traditional CS1 class.

On a final survey, students in the *Media Computation* class were asked what was the most important thing *not* to change about the class. Nearly 20% of respondents named the collaboration tool CoWeb and over 20% mentioned collaboration in general. Certainly, the media context influenced students' interest in the material and motivation to say in the class. But the context in which the media is manipulated is important to student affect, too [34]. Wedo not know the relative influence of the course context vs. collaboration (and collaboration vs. CSCL) in the improved retention in this course, but student responses on the final survey suggest that collaboration may have played a significant role.

### 1.2.1 The Possible Roles of CSCL in Improving Retention

Why should collaboration play a role in improving retention, if it does? That's one of the significant research questions of the proposed research. We do have some early hypotheses.

We believe that the most significant influence of CSCL is by enabling collaborative learning activities which impacts on student interest and motivation, factors in retention [12]. These factors are particularly important in student's project work. SMET education is often project-based [1, 3]. Students work on external projects in the course, often requiring multiple sessions to complete. Sustaining motivation is a critical factor in project-based learning [4] and technology in general can play a role in sustaining that motivation [35]. If students are interested in the project, they tend to be more successful at it [29], and technology can play a role in maintaining interest [30].

One of the factors that influences a students' motivation to remain in the class is a sense of anonymity [12]. If a student will be missed if she doesn't attend class, there is more motivation to attend class. This is one of the explanations for lower retention in large lecture-based classes. In a class that uses face-to-face collaboration heavily (as in pair programming), you will always be missed if you do not attend. Your collaborators rely on you.

CSCL (at least, when the technology is asynchronous and text-based) does not influence the same factor in the same way. While students may develop a sense a community in the on-line space [7], thus reducing the sense of anonymity, there is not the same pressure to physically be present in class. Nonetheless, CSCL can inculcate some similar motivation to remain a part of the class.

Our analysis of interviews with students in the *Media Computation* class suggests that CSCL influences both motivation to continue in the course and student interest, and perhaps helps with a sense of community . The particular role that CSCL plays is not unlike the role of a case library in supporting project-based learning [19, 33]. CSCL can serve as a *source for models* for both process and product and a *source for lessons-learned*, as a *source for feedback* well as a place to get questions answered.

- As a *source for models*, we found that students used the CoWeb to find out what others have done (e.g., in the *Galleries*) to be used as examples. They would also use students' questions in the CoWeb to guide their own process.

  **Q. What do you think about the homework galleries on the coweb?**

  **Student 2:** "Oh like where you can put your picture up. It's nice to see other people, like what they did with it. Cuz, I'm not the most creative person and even if I was I wouldn't know how to be creative in this! And there is no better feeling than getting something done and knowing that you've done it right, like the Soapbox sometimes is just like 'I did it!' and posting to the CoWeb just adds onto that."

- As a *source for lessons-learned*, we found that students would go to the CoWeb when first starting a project to see the challenges that others were facing and sometimes to jump-start their own process.

  **Q: Do you think the CoWeb is beneficial? Why?**

  **Student 1:** "Very beneficial, it keeps you on track, keeps you organized. You get to see what people are having problems with and maybe see... I always start off looking at what people have had problems with."

  **Q. How do you plan to study for the final exam?**

  **Student 2:** "Hard. I have actually read the book. I read it before the first test. I'll go through all the lecture slides and look at old tests. And the online review [on the CoWeb] is awesome and I'm very grateful he did that. I like that you can make comments, I can see stuff where other people had questions cuz they ask stuff that I might not have thought of. And I'll study with a group."

- As a *source for feedback*, the CoWeb served as a place to ask questions, inform others where you were in your process (e.g., the Soapbox comment above), and to get feedback on the clarity of your process. Anonymity, which is not possible easily in face-to-face collaboration, played a role in putting students at ease in asking questions—an important factor in retention [55].

  **Q. Have you ever posted to the CoWeb?**

  "I think I've posted to everything. Sometimes I'll just make random comments. Sometimes I ask a specific question and he [the professor] asks for clarification."

  **Do you think the CoWeb is beneficial?**

  "Yes. And there's no reason to feel uncomfortable because if you feel dumb, just don't put your name at the end! I did that a few times. "

## 1.3 When CSCL Fails to Improve SMET Learning and Retention

At the same time that we know that collaboration, and CSCL specifically, *can* play a role in learning and retention, we also know of specific SMET learning situations where it does *not*. Part of our work on our NSF REPP grant (#REC-9814770) involved coming to understand where collaboration is *actively resisted* in SMET classes.

The initial focus of the project 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 [11].

Our plan was to provide a collaboration space, CoWeb (or Swiki), which was being used successfully in several other courses [22]. The idea was to provide a place where students could go for help on any aspect of computer modelling, 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 efforts.

- To encourage collaboration in 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 CoWeb in a 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 palettes, 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 found three main reasons for the lack of collaboration [21, 20]:

- *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.

The conclusion is that CSCL is no panacea. Students will not necessarily participate, and without participation, we can have no impact on learning nor retention. Thus, any theory that attempts to explain how CSCL might influence retention must take into account classroom culture and inculcating student interest even in the collaboration itself.

## 1.4 Articulating a Theory of CSCL and Classroom Culture Influence on Retention and Student Performance

We can now articulate our early theory of how CSCL and changes in classroom culture. Figure 1 describes how we hypothesize that introducing CSCL with requisite changes in classroom culture can influence student withdrawl rate and student performance.

Our main inputs into the system are (a) a CSCL environment that easily enables collaborative learning activities and (b) encouraging faculty members to provide support for collaboration through change in classroom culture. Both are necessary to make collaborative activities successful: The technology makes it low-cost and easier to adopt [45] and the policy changes are critical to change culture and encourage participation [21]. Collaborative activities encompass student experiences from *explicitly* collaborative activities created by and/or sanctioned by the course instructor through collaborations that the course instructor allows and *implicitly* encourages by a liberal collaboration policy and a grading policy that does not penalize students for working together. We have learned that the implicit encouragement is perhaps more critical for successful participation in collaborative activities than the explicit encouragement [21, 20], but the explicit encouragement is noted by the students (see quotes above) and does have an impact.

With the opportunity to collaborate enabled by collaborative learning activities and encouraged by a supporting culture, we believe that student participation is enabled based on our prior work [21, 20]. We can then explore the specific hypotheses of this project.

- We believe that this participation in collaborative activities influences students' interest and motivation to succeed in the course. It may also influence activities like question-answering and developing a sense of community, which can influence retention.

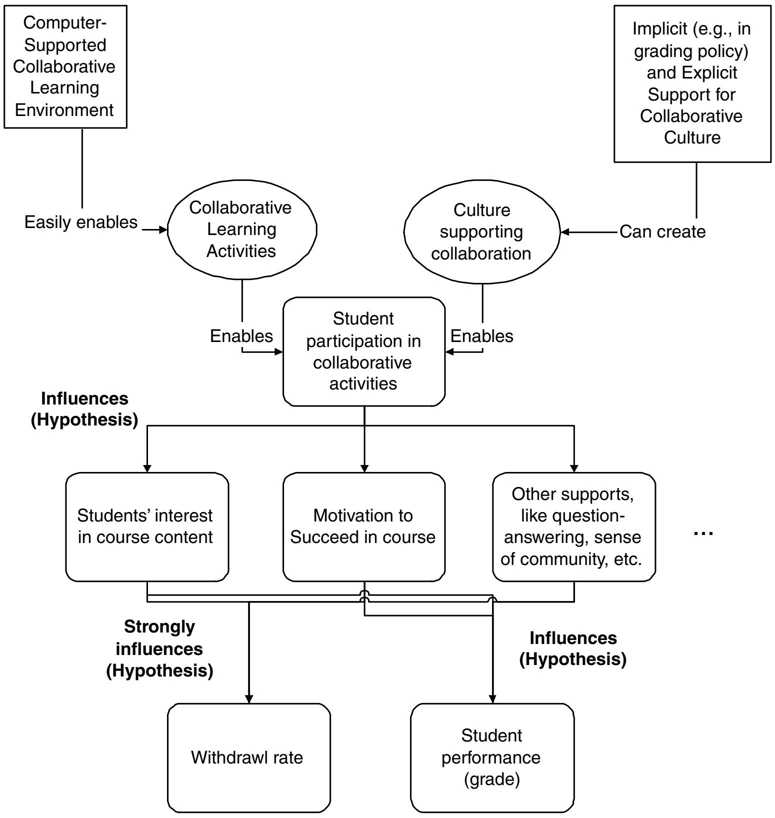


Figure 1: Diagram of hypothesized influences

- We believe that the strongest influence of these influences (from the collaborative activities) is on the withdrawl rate—convincing students *not* to give up on the class. This is the effect on retention that we're most concerned with and that we see in the earlier cited studies [40, 17].
- We believe that there is an additional influence on student performance, seen in terms of grades.

Our project plan is about (a) investigating the research questions implied by these hypotheses (e.g., are these hypotheses correct? What other factors need to be considered in our model of influencing retention?), (b) testing our answers to these questions, and (c) applying our answers to improve the phenomena in question.

# 2 Project Plan: A Practice-Driven Process for Research, a Research-Driven Process for Impacting Practice

The process that we are proposing in this project means to coordinate research with practice in such a way that we learn more about practice and directly impact the practice. The research starts from a real problem in practice, and then proceeds to develop a process for applying the results of the research in practice to address the original problem. Our proposed project seeks directly to improve retention in SMET undergraduate classes using interventions based on CSCL. We use the projects described [17, 40] as evidence that collaboration *can* have an impact on retention. Our proposed work seeks to understand when collaboration may be successful at improving retention, test our understanding, and then apply that understanding to change classes with historically low retention rates.

This is a different model than most research in the learning sciences, and we think it's an important one. While it's in the vein of a design experiment [5], our goals are somewhat different. Like a design experiment, we begin in real classrooms with all of their complexity, and our goal is to understand better what's going on in the situation. But while a design experiment seeks to understand individual student psychology, our work seeks to understand the classroom dynamics and not focus on the individual student. In some sense, our approach is more of an engineering approach than a scientific approach. While scientists seek to understand all of a phenomenon, an engineer studies enough to make it work [32]. In so doing, the engineer often gathers the data that drives the scientific enterprize. We plan to play that kind of role. We plan to learn how to directly affect retention rates through manipulation of factors related to collaborative learning, and then use that knowledge to impact courses with historically low retention rates.

A brief sketch of our plan follows:

- Year One: We develop a theory about how classroom culture and collaboration practices relate to retention, by studying some of the 40 courses per term that use our CoWeb collaborative software and by studying comparable courses that do not use any form of collaboration. We essentially want to develop a qualitative regression equation that describes how factors such as perception of competition and the availability of models relate to intermediate factors such as student interest and motivation which drive our factor of interest, retention.

- Year Two: We then test our theory and develop an intervention strategy. Each term during Year Two, we will select a sample of courses, some using CoWeb and some not using collaborative learning activities at all, and develop a prediction based on our theory of anticipated retention. We use CSCL because we expect that if will be the easiest for teachers to adopt in our Year Three efforts. We will study those courses (e.g., use surveys to establish student interest and motivation in the course) and refine our theory.

- Year Three: We apply our theory. Given our theory, we will develop a system to identify courses with historically low retention rates which might be amenable to our interventions, e.g., changing grading practices to reduce competition, and provide models and discussion spaces via CoWeb. We will work with faculty in those courses to bring about change, and then measure our factors to look for impact of our intervention and match to our theory.

## 2.1 Year 1: Creating a theory about retention

During the first year of the study, we plan to develop a theory about how collaboration impacts retention. We are not under any illusions that collaboration is the *sole* factor impacting retention in any post-secondary course, however we do believe that collaboration can be a *significant* factor, and it is a factor that we have some control over.

Our strategy for developing a theory about collaboration is to measure these variables in studying four kinds of classes. We will choose a sample of each of these classes to study during each of the three semesters in Year 1, for a total of some 20 courses over the course of the year.

- SMET classes with high retention. Our analysis of courses at Georgia Tech suggest that high retention may be a relative concept—rarely in first and second year courses is the WDF rate (percent of enrolled students who Withdraw, or who earn a grade of D or F) in single digits.

- SMET classes with historically low retention. Table 1 summarizes the WDF (Withdraw, or earned grade of D or F) rates of several potential target courses at Georgia Tech.

- Similar SMET classes using collaborative activities. Not all sections of these courses are taught in the same way—the statistics hide the activities of particular instructors and the use of collaborative activities within those classes. We do not have evidence right now that there *are* sections of similar classes that are using collaborative activities without technological support, but we plan as part of our survey to seek out these kinds of activities.

- As a significant subset of the second kind, we are interested in similar SMET classes that are using CSCL for collaborative activities of some kind. We know that simply using CSCL tools does not imply participation nor successful learning [21, 20]. However, use of a CSCL tool indicates the potential for incorporating successful collaborative learning activities, and use of a tool is easier to incorporate into courses that have no collaborative component.

  Moreover, CSCL-using classes with low retention help us to understand better what CSCL can impact and what it cannot. We have hypotheses about what CSCL can impact and under what conditions. We don't believe that CSCL can influence *all* the factors that lead to better retention. However, we believe that we can reduce retention rates because there's *enough* leverage through CSCL.

At Georgia Tech, there are a reasonable number of courses in that last group of SMET classes. Last semester, some 45 classes used our CoWeb collaborative technology. Some 20 of these were in Computer Science, 5 in Mathematics, and another 10 were in Chemical Engineering. Currently, *all* undergraduate Chemical Engineering classes are automatically provided with a CoWeb at the start of each semester. There are other collaborative technologies in use at Georgia Tech as well: WebCT and newsgroups, for example. We will include those tools in our study, but based on our comparisons between different tools, we feel that the CoWeb is the most flexible and thus will be the most applicable to the widest range of kinds of classes [22, 23, 15].

We believe that collaboration impacts retention through at least two direct variables that CSCL has the opportunity to impact.

- **Interest**: Collaboration can encourage and inculcate student interest. We see (e.g., in earlier quotes) that students are inspired by the work that they see other students doing. We know that student discussions do inspire students to explore issues more deeply [18].

- **Motivation to succeed in the course:** Collaboration can help convince students that they can succeed (as well as potentially help them learn so that they can succeed). Collaboration can help in answering questions, in receiving support in the course, and in reducing students' sense of anonymity (unless they want it!). In general, collaboration can make the class seem more *doable*—that it's something that students can be successful at.

We know from the literature that there are many other factors that influence retention [42]. Some of the more significant ones that we plan on studying:

- Number of students in a class or section. Obviously, the number of students doesn't *directly* lead to students' failure to succeed at a course. However, more students in a class leads to a greater sense of anonymity which can influence students' decision to withdraw or skip class [12]. Greater numbers may also inhibit's students' comfort with asking questions, which has been highly correlated with success in introductory computer science courses [55].

- The instructor plays a very significant role in retention in a course. We've found that instructors' attitudes and modelling of behavior influences students perceptions about the course [21, 20].

- Student self-perceptions about efficacy in the class [52]. If students enter a class convinced that they won't be successful, they probably won't be. Student perception that the situation is manageable improves motivation to succeed [41]. To what students attribute their efficacy

| Course | Title | Term | $N$ | W | D/F | DFW |
|---|---|---|---|---|---|---|
| CS1050 | Understanding and constructing proofs | Fall 2001 | 234 | 10.68% | 14.10% | 24.79% |
| | | Fall 2002 | 213 | 4.23% | 17.37% | 21.6% |
| CS1321 | Introduction to Computing | Fall 2001 | 1168 | 7.96% | 21.06 % | 29.02% |
| | | Spring 2002 | 935 | 8.88% | 25.99% | 34.87% |
| | | Fall 2002 | 1316 | 7.07% | 18.77 % | 25.84% |
| | | Spring 2003 | 879 | 10.69% | 27.08% | 26.02% |
| CHE2100 | Chemical Process Principles | Fall 2001 | 87 | 6.9% | 10.34% | 17.24% |
| | | Spring 2002 | 31 | 0% | 25.81% | 25.81% |
| | | Fall 2002 | 90 | 8.89% | 16.67% | 25.56% |
| ECE2025 | Introduction to Signal Processing | Fall 2001 | 304 | 8.88% | 9.54% | 18.42% |
| | | Fall 2002 | 272 | 6.25% | 9.19% | 15.44% |
| Chem1311 | Inorganic Chemistry I | Fall 2002 | 136 | 10.29% | 25.74% | 36.03% |
| Math1501 | Calculus I | Fall 2001 | 1421 | 3.31% | 17.8% | 21.11% |
| | | Spring 2002 | 225 | 7.11% | 42.22% | 49.33% |
| PHYS2211 | Introductory Physics I | Fall 2001 | 634 | 9.31% | 29.02% | 38.33% |

Table 1: A selection of Withdraw, D, or F rates for lower-division undergraduate courses at Georgia Tech

is also correlated with success in the course. Students who do not succeed in introductory computer science courses tend to attribute their performance to external factors such as “luck” as opposed to internal factors such as “hard work” [55].

Our plan is to conduct surveys and interviews among teachers and students (both those who complete the course and those who do not). Our study plan is described in Table 2. The idea is to study the courses at Georgia Tech that can inform us about retention and about the role that CSCL is and might play with a focus on the variables that are identified in the literature and in our own work that are significantly related to retention. Where possible, we plan to use and adapt existing measures for these factors, such as the MSLQ for measuring motivation that has been used successfully with undergraduate students [43].

## 2.2 Year 2: Testing the Theory and Defining the Intervention

Based on our study in Year 1, we will develop a theory that will allow us to predict retention rates. During Year Two, we will apply that theory to develop *a priori* predictions about retention in the courses. We will then replicate the study of Year 1 to gather data to refine the theory. At the end of each term, we will establish the reliability of our theory. By the end of Year 2, we expect to have reasonable accuracy at predicting retention rates.

Even from the start of Year 2, though, we will have a good idea of what factors are most significantly related to retention in our target classes, and which variables might be influenced by CSCL. During Year 2, we will develop our intervention plans—determining what factors we might

| Class of participants | Factors to be studied | Frequency | Form of measurement |
|---|---|---|---|
| Faculty | Attitudes toward collaboration, attitudes toward student efficacy and achievement, policies toward collaboration, collaborative activities in the class | Before class starts | Surveys and interviews in particularly low-retention classes |
| All students | Interest in the course, motivation to succeed in course, comfort asking questions, perceptions about course | First week of course | Surveys |
| Students who drop the course | Interest in the course, motivation to succeed in course, reasons for dropping the course, perceptions about course | After drop day | Interviews (including phone and email) |
| Students who complete the course | Interest in the course, motivation to succeed in course, expected grade in course, cause of grade, perceptions about course | End of class | Surveys and interviews with a sample of volunteer students |

Table 2: Study plans in first year in targeted courses

influence via CSCL, and then developing materials and activities for the target classes which will focus on those factors.

Obviously, not all factors, not even all significant factors, will be amenable to intervention using CSCL. However, we do believe that CSCL will be able to play a role in *reducing* failure rates in targeted courses. We will begin with our hypotheses about the roles that CSCL can play in influencing retention: a *source for models* for both process and product, a *source for lessons-learned*, and a *source for feedback* well as a place to get questions answered.

To prepare for intervention, we will create:

- Activity materials for teachers, like our successful *CoWeb Catalog* [36] that describes activities that teachers have invented with the CoWeb [22]. The new materials will focus on activities that will directly impact the factors that we decide are most amenable for change. The idea is to show teachers ways that they can incorporate the CoWeb to improve retention in their courses.
- Course suggestion materials which will describe how to change grading policies or influence course perception in ways to improve retention.
- In some instances, modifications to our CoWeb software to make it easier to implement these activities and suggestions.

## 2.3 Year 3: Applying the Theory and Interventions

Year 3 is about directly applying the theory and materials that were developed and verified in Years 1 and 2. There are two parts to our goals for Year 3:

- We need to identify target courses for improving retention.
- We need to implement the interventions.

### 2.3.1 Identifying Target Classes

We plan to develop a process for selecting courses for intervention. The goal is to find courses that are most amenable to intervention and improvement, and to systematize the process so that such targeting and intervention can become a regular practice in the institution. The process we are currently planning includes:

1. Identifying potential target courses based on historically low retention, e.g., WDF over 20%.
2. Survey of teachers for those targeted courses in Year 3, to determine which ones would have attitudes and policies most amenable to intervention.
3. Approaching these teachers with our materials and asking them if they would be willing to change their activities and policies.

We have the support of Robert McMath, Georgia Tech's Vice-Provost for Undergraduate Education, that we can use in providing legitimacy to our effort. We will also be working with Donna C. Llewellyn, the Director of Georgia Tech's Center for Enhancement of Teaching and Learning. Dr. Llewllyn has a great deal of experience in working with faculty and encouraging changes in classrooms. We will be seeking her advice on how to handle Step 3 in the most effective manner.

### 2.3.2 Implementing the intervention

Once we have identified a willing teacher, we plan to work with the teacher through regular meetings to help him or her implement the activities and changes that our theory will recommend. We do *not* plan to be cautious and objective observers. Our hope is to cause a change in retention rates. We hope to see an institutional change such that the intervention becomes permanent, but that's beyond the scope of this project. Our goal here is to cause a change through targeted intervention. While we recognize that we will be susceptible to a Hawthorne effect, we agree with Ann Brown that that's a desirable outcome as part of a process leading to deeper and persistent change [5].

We will record the amount of effort used in the interventions, as we have in prior studies [45]. Our belief is that CSCL will allow for a relatively easy to implement change that will impact retention. We plan to measure how easy that is. Our current plan is to probe the teachers on a regular basis to get estimates of how much time the intervention is requiring. Our evidence from our work in English Composition classes is that the cost in teacher time to adopt CSCL activities is negligible [45], but we recognize that SMET faculty may not recognize their situation as being similar to an English composition classroom. By tracking that time-cost data, we can report it to targeted faculty in subsequent semesters to show that the cost is minimal. We hope that the low cost, with the evidence for improved retention across the first two years of the study, will help to convince faculty to try our approach.

During the intervention, we will continue to gather data as described in Table 2 so that we can match progress to our theory. In this way, we hope that we can learn about both the process of change of retention rates in the classes.

## 2.4 Project Roles and Involvement of Students

Mark Guzdial will be the PI of the project. He will be responsible for overall management of the project and the achievement of project and dissemination goals.

Allison Elliot Tew will be a Research Scientist on the project. For four years, Allison has been the Director of Student Services. She's familiar with the systems for gathering data on classes, and with the task of encouraging and cajoling faculty into behavior for the students' best interests. She also has prior experience in project management and software engineering. She'll handle the day-to-day management of the project, and will be the main person developing the measurement instruments used in the project, reviewing the data and results, developing the theory, evaluating the theory, developing the interventions, and working with faculty to implement the interventions.

We will hire two Graduate Student Research Assistants (GSRAs) on the project. Their responsibilities will include:

- Data collection and analysis, including interviews,
- Developing and maintaining software associated with the project,
- Developing materials for the interventions,
- Providing support to the teachers as they begin the interventions.

In addition, we anticipate working with individual students who will join us looking for research opportunities. We have been very fortunate in finding talented students who are interested in the goals of our projects. For example, on the *Media Computation* course project, all the interviews were undertaken by a talented undergraduate student, Lauren Rich, who wanted to study gender issues in the course. In this way, we hope to be able to explore particular angles and offshoots of the project as the arise, while involving additional students.

### 2.5 Dissemination Plans

Primarily, we hope to disseminate our results to two audiences:

- Learning Scientists (e.g., *International Conference of the Learning Sciences*, *Computer-Supported Collaborative Learning Conference*, and *Journal of the Learning Sciences*) who will be interested in our theory of retention related to CSCL, our intervention plans, and our results, as well as our process for targeting and intervening in low-retention classes.
- SMET teachers and administrators who will be interested in mechanisms for improving the poor retention rates in these classes. We anticipate reaching Engineering and Computer Science educators through the IEEE/ASEE *Frontiers in Education (FIE)*, ACM *SIGCSE* (SIG Computer Science Education), and *Innovation and Technology in CS Education* (ITiCSE) conferences. We also hope to publish in *IEEE Transactions on Education* and *Journal of Engineering Education* as high quality and visibility forums for this research.

As we target courses in other disciplines (e.g., Mathematics and Physics), we plan to reach out to those audiences as we have with our previous CoWeb work (e.g., [39, 26, 44]).

We anticipate to have two conference papers per year, and at least two journal papers over the course of the three year project. In addition, we will make all of our intervention materials and our software available on our websites.

Our websites have been an effective mechanism of intervention for us. Our CoWeb/Swiki software and associated materials are posted there, indexed by Google. A search today for "Swiki" on `http://www.google.com` returns 126,000 hits. A review of the first couple hundred of these hits shows that the vast majority of hits are sites using our software (available at `http://minnow.cc.gatech.edu/swiki`). 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.

## 3 Conclusion

The overall focus of our project is to conduct research targeted at a significant and stubborn problem in SMET courses. Our approach is to study the problem and our potential solution to the problem, to develop a theory and test our theory about the problem, then to apply an intervention based on our theory. Our potential solution is collaborative learning activities, implemented through CSCL.

We don't expect that we will be able to make 90% of students succeed in every SMET class at Georgia Tech. But if we can lower some of the 20–30% WDF rate classes into the 10–20% range, we will have accomplished something significant, since we will have carefully engineered and documented our process of intervention. In addition, our process of choosing a research question in terms of practice and then addressing that question will serve as a model for future joint practice-research agendas.

## 3.1 Budget Justification

*Personal Services.* We request 1 month of summer salary for Mark Guzdial per year, and 12 months of Allison Tew per year, for all three years of the grant. In addition, we request funding and tuition for the two GSRA's on the project. We also request funding for 1/2 of a shared post-doc for maintenance of laboratory equipment in the GVU Center. We are requesting fringe and computing charges for these personnel.

*Equipment*: None is requested.

*Travel*: We request $4,000/year for travel expenses for attending conferences where we are presenting results from this work (predicting two per year).

*Materials and Supplies*: We ask for $2,000/year for miscellaneous expenses, like toner cartridges and software upgrades.

# 4 Facilities

The College of Computing maintains a variety of computer systems in support of academic and research activities. These include more than 50 Sun, Silicon Graphics, and Intel systems used as file and compute servers, many of which are quad-processor machines. In addition, there are more than 1,000 workstation class machines from Sun, Silicon Graphics, Intel, and Apple especially for student use. A number of specialized facilities augment these general-purpose computing capabilities. The hardware that will be purchased for this project will be of similar quality to what the students use, for testing purposes, but will be set up to facilitate development.

The Graphics, Visualization, and Usability (GVU) Center houses a variety of graphics and multimedia equipment, including high-performance systems from Silicon Graphics, Sun, Intel, and Apple. The affiliated Multimedia, Computer Animation, Audio/Video Production, Usability/Human Computer Interface, Virtual Reality/Environments, Electronic Learning Communities, Computational Perception, Software Visualization, Biomedical Imaging, Collaborative Software, and Future Computing Environments labs provide shared facilities targeting specific research areas. These laboratories' equipments will be of use in developing our multimedia projects.

PI Guzdial is the Director of the Collaborative Software Lab, affiliated with GVU. The Collaborative Software Lab has a bank of ten servers supporting our experimental software for studying computer-supported collaborative learning. In addition, we have three Linux workstations, two NT workstations, and two Apple workstations used for development. The focus of the Collaborative Software Lab is on facilitating multimedia collaboration, so multimedia facilities available include a high-end Alesis keyboard, projection facilities, a Canon digital video camera, and a Nikon digital camera.

All of the College's facilities are linked via local area networks which provide a choice of communications capabilities from 10 to 1000 Mbps. The College's network employs a high-performance OC12C (622 Mbps) ATM and GigabitEthernet (1000 Mbps) backbone, with connectivity to the campus ATM network provided via OC12C. The primary campus Internet connection is provided by a direct 100 Mbps link to the service provider's Atlanta switching center, augmented by OC3C ATM and OC12C connections, respectively, to the NSF vBNS (very high performance Backbone Network Service) and Abilene research networks. Georgia Tech is also leading southern regional gigabit network efforts (SoX.net, the Southern Crossroads) as part of Internet2.

Additional computing facilities are provided to the Georgia Tech campus by the Institute's Office of Information Technology (OIT), including five public-access clusters of Sun, Apple, and Dell workstations, a collection of Sun multi-processors which are treated as a single computational resource via login load sharing, and various mainframes.

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