The challenge of collaborative learning in engineering and math

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Abstract— **The CoWeb is a collaborative learning technology used in many classes (over 100) at Georgia Institute of Technology (*Georgia Tech*). We present evidence of the success of the tool in supporting learning at a low cost. But we also provide anecdotes about the *active resistance* we've received to use of the CoWeb in Engineering, Mathematics, and some Computer Science classes. Evidence from interviews and questionnaires points to some of the sources for this resistance.**

Keywords— **Educational technology, collaboration, attitudes, learning**

I. CoWeb: Collaborative Website

Collaboration is an important aspect of engineering education. Professional engineers work with one another and with professionals in various domains. These engineers must learn to interact with others, critique others' work, and accept criticism and alternative viewpoints. Engineering education reformers have called for increased collaboration in students' activities to prepare them for the professional reality [1], and ABET has made collaborative activities a requirement in their accreditation criteria [2]. Researchers in computer-supported collaborative learning (CSCL) have shown that technologies can enhance collaboration and make it feasible where it wasn't previously [3]. It makes sense, therefore, to explore how collaborative technologies successful in other domains might be applied to engineering education.

The CoWeb (Collaborative Website)[1] is a technology that provides perhaps the simplest possible model for collaboration. A CoWeb is a website where (to oversimplify) (a) each page is editable by simply clicking an *Edit* button on the page and (b) new pages can be created by simply referencing them in the page's text, e.g. `*New Page*`. Through over a dozen iterations in the last three years, the CoWeb has had features added and the interface simplified to fit well into classroom use [4]. Over 100 class CoWebs are now in use at Georgia Tech. A wide variety of educational activities have been invented by teachers for their classes [5], and we have catalogued some 25 core activities that we see tailored to meet specific class needs [6].

When it works, we find the CoWeb to be quite successful. We find students voluntarily using the site. We find evidence of improved attitudes toward collaboration, and some evidence of better performance suggesting better learning. We are actively tracking the costs of implementing the CoWeb in a classroom, and find that the costs are surprisingly low.

However, we find the CoWeb to be surprisingly unsuccessful in Engineering, Mathematics, and some Computer Science classes. Students refuse to participate, or only participate to the extent required. Teachers and teaching assistants ignore the CoWeb or actively fight against it.

In this paper, we provide evidence that the CoWeb *can* be successful, and provide some more details of the *active resistance* that we see in some classes to the CoWeb. We have been conducting interviews and questionnaires to understand the source of this resistance, and we present those findings here.

II. CoWeb Success Stories

We have had marked success with the CoWeb in a wide variety of classes. In particular, Computer Science, Architecture, and English Composition have provided us with powerful examples of how successful collaborative technologies can be in a classroom.

- In Computer Science, the CoWeb has been used in a variety of classes for many different activities [7]—literally, thousands of students in dozens of classes. For semester-long projects (e.g., in a *Digital Video Effects* class), the CoWeb can serve an important role in benchmarking progress and leaving a trail of design decisions and partial artifacts. A particularly popular activity (e.g., in a class on object-oriented analysis and design) is the *Midterm Exam Review* where potential midterm exam questions are posted, and students respond with answers, questions about the questions, and questions about each others' answers.
- In Architecture, the CoWeb is used for posting student work for peer students and even outside experts to comment upon, as well as conduct debates and share research findings [8]. Architecture students like the CoWeb, feel it integrates well with the class, and tend to use it more than is strictly required (Table I). The quote[2] below from one student exemplifies their attitude.

"The best part of this course was using *trescool* [their CoWeb]. It helped in keeping up-to-date with the class and upcoming assignments. It was also helpful to have a question and answer page for our midterm papers and final research projects... At Georgia Tech, the classes that I am

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[1] Available at `http://coweb.cc.gatech.edu/csl`

[2] All quotes in this paper retain their original spelling and capitalization

taking do not use their websites as much. I think if a class is going to create a site at all, it should be as helpful as *trescool*."

• In English Composition, the CoWeb is used for an activity called *Close Reading* where a prose or poem for discussion is posted, and students comment upon by inserting links directly into the prose or poem. Students then comment upon each others' comments, and even then use the same technique to comment upon each others' essays.

We have been studying use of the CoWeb in an English Composition class ($n = 24$) in comparison with the same class taught by the same teacher ($n = 25$). We find that the CoWeb-using class had significantly better attitudes toward collaboration on surveys than did students in the comparison class (Table II)[3]. In addition, the CoWeb-using class received higher grades (grade breakdown: 7 A's, 10 B's, 3 C's, others F or W) than the comparison class (grade breakdown: 19 B's, 3 D's, others F or W), which suggests[4] better performance and perhaps better learning. We have recently completed a multi-rater comparison of students' essays in the CoWeb and non-CoWeb classes, and have found that CoWeb using students were significantly more successful in measures of essay organization and vocabulary, where the non-CoWeb using students were not better under any of our measures.

Statement	% Students Agree or Strongly Agree
I like using the CoWeb	44.9%
It fits with the activities in this class	55.1%
I use it more than the minimum required.	40.8%

TABLE I

Architecture students attitudes toward CoWeb

We have also been tracking cost for implementation of the CoWeb in these courses, in order to determine the cost/benefit ratio for implementation of the CoWeb.

• Hardware costs are negligible. In only one of the above cases was a server purchased for the course. The CoWeb is a cross-platform and very efficient program that can be run on virtually any hardware (in some cases, old 486's). We serve literally dozens of classes on five year old Macintoshes.

• We tracked system administration of the software, and found that no system administrator spent even an hour of time over the course of the semester to maintain and administer the sites.

• We also tracked teacher time in using the CoWeb, through weekly diaries. One Math instructor found that he spent an additional 75 minutes per course per week in dealing with the CoWeb. The English Composition instructor spent an additional 150 minutes per course per week in dealing with the CoWeb. The difference between these two might be due to the teacher handling the system administration burden: The Math instructor ran a CoWeb on a UNIX server whose overall (beyond the CoWeb) administration was handled by his department, while the English Composition instructor maintained her own Macintosh server. Nonetheless, the amount of time is low, approximately that of an additional *Office Hours* session.

Statement	CoWeb Class	Comparison Class
I would rather work independently on assignments than in groups or teams.	3.83	2.81*
I feel like working with others on assignments is more helpful than working alone.	2.00	2.75*
I found it useful to relate my work to that of others.	1.56	2.50**

TABLE II

English composition students (CoWeb-using and comparison) attitudes toward collaboration, where 1 is strongly agree and 5 is strongly disagree. * is $p < 0.05$, ** is $p < 0.01$

• We also tracked student time, to see if benefits due to the CoWeb were being bought in student effort. We paid five to ten students in each class $25 to record their time outside of the classroom on class material. In comparing two Mathematics classes, CoWeb-using students spent an average of 73.7 minutes per day (standard deviation 42.9) doing homework and otherwise working for the class, while the comparison students (same class, but different teacher) spent an average of 73.4 (21.4) minutes per day — a negligible difference.

In general, then, the CoWeb can be quite successful, across both Architecture and Composition classes[5]. It is encouraging student participation, and they like it. It may be playing a role in increased learning and improved attitudes toward collaboration. It seems to be achieving these benefits with very low cost.

III. CoWeb Failure Stories

However, the story is somewhat different in the Engineering and Mathematics classes in which we have trialed the CoWeb. We have trialed many different activities using the CoWeb over the last three years [6]. Our most successful activity was the *Puzzle* activity where the teacher posts a challenging problem on the CoWeb, and offers ex-

[3] The p-values here were from a Students' T test. The discrete values call for a different kind of test, and we're exploring what are the best measures to apply. Nonetheless, the t-test p values provide a ballpark measure of significance.

[4] We recognize that these data only *suggest* a learning benefit. Grades are not a careful measure of performance, and they are too large-grained to inform us about *where* any learning benefit may be coming from.

[5] The low n in Composition classes does not prohibit us from claiming that it *can be* successful. The interesting question to explore is *when is it NOT*?

tra credit for the solution *or* for posting a partial solution or lead that results in the solution. Approximately 40% of the class voluntarily participated in that activity, which is still a far cry from the 70-100% participation that we see with other kinds of classes (e.g., [9]).

Some anecdotes highlight the kinds of *active resistance* that we have seen.

- 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.
- Freshmen at Georgia Tech take a required course *Introduction to Computing* which includes a two week segment on MATLAB. We created a MATLAB CoWeb to encourage peer support in learning MATLAB programming, and we populated it with question-and-answer pages, tutorials, and reference links. The Teaching Assistants refused to tell their students about it, arguing that it would only confuse the students.
- 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 GIF renderer 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.

These anecdotes paint a stark picture of active resistance to collaboration. These students simply showed no interest in collaborating at all, and at times, willingly accept a decrease in their grade rather than collaborate. Further the teaching assistants in the Computing course only exemplified an attitude that several engineering faculty have told us: That they don't consider collaboration an important part of undergraduate learning. We don't see that students *want* to collaborate but are having trouble with the technology or with figuring out how best to collaborate—if that were true, we would expect to see students *trying* the technologies and more than 22 students out of 340 students posting. Rather, we see students actively avoiding collaboration, which poses an important problem for engineering educators who want to use computer-supported collaborative learning.

IV. Explaining the Resistance

We have been conducting interviews and questionnaires to try to understand what's going on in these classes. For example, we recently introduced the CoWeb into an English Composition class (same class described earlier in a comparative study), a Mathematics class, and a Chemical Engineering class the same semester. Some of the results of an end-of-term survey are summarized in Table III. We see that the Composition class was more positive about the CoWeb and about collaboration in general than the Mathematics and Chemical Engineering classes.

Statement	**Comp**	**Math**	**ChemE**
I enjoyed using the CoWeb	2.17	2.52	3.18
I would rather work independently on assignments than in groups or teams.	3.83	3.40	3.59
I feel like working with others on assignments is more helpful than working alone.	2.00	2.36	2.41
I found it useful to relate my work to that of others.	1.56	2.52	2.47

TABLE III
Comparing average responses to statements about the CoWeb and collaboration between Composition, Math, and Chemical Engineering classes (1 is strongly agree, 5 is strongly disagree)

In another study, we used a *Midterm Exam Review* activity (described earlier) in a Chemical Engineering class and in a Computer Science class—and in both classes, there was almost no participation. We used a targeted questionnaire to explore our hypotheses for why there was so little participation, and some of the results are summarized in Table IV. In the Chemical Engineering class ($n = 24$), 90% of the students said that they were aware of the Midterm Exam Review, and 70% said that they found the review useful—but mostly to do on their own. In the CS class ($n = 150$), 87% of the students said that they were aware of the Midterm Review, but only 55% found it useful. However, note that the students generally agree with the statement that "Posting solutions for comments or questions to the CoWeb is useful." We will return to these results as we describe what we see as the explanations for the active resistance to collaboration in these classes.

Statement	ChemE	CS
Posting solutions for comments or questions to the CoWeb is useful	2.5	2.6
I find the course to take a lot of time outside of class time	1.8	2.2
I view [this field] as intensely competitive	2.1	2.6
I view [this class] as intensely competitive	3.6	2.5
Most of the problems in this class have only one correct answer	2.1	3.7
The CoWeb is primarily an information resource	2.8	2.9
I print pages from the CoWeb regularly	3.7	3.8

TABLE IV

Average responses to statements about the CoWeb between a Chemical Engineering and a Computer Science class (1 is strongly agree, 5 is strongly disagree

A. Competition and Single-Answer Assignments

Students in the classes where there was little collaboration tended to view the class or the field as competitive and demanding a lot of time and effort. The results of Table IV support that result, as did interviews that we did with students. Quotes from the targeted questionnaire on why students did not participate in the Midterm Exam Review activity provide more evidence for this claim.
"1) didn't want to get railed 2) with the curve it is better when your peers do badly"
"since it is a curved class most people dont want others to do well"

Students in Engineering and Mathematics, particularly, tended to see their homework as having only one correct answer (Table IV)—even when faculty told us that this wasn't true. It was just the students' perception. The classes where the CoWeb have been most successful (e.g., English Composition, Architecture, object-oriented design, video effects) have been classes with a heavy emphasis on design and where there are many correct answers to a given project assignment. If there's only one correct answer, and the class is highly competitive and/or curved, it's only rational *not* to collaborate or help others. It is in the students' best interests not to participate.

Research on collaborative learning in general also tells us that the perception of single-answer assignments is a hindrance to collaboration. Cohen [10] in her review of the literature on collaborative learning found that open-ended, ill-structured problems tend to encourage productive group learning. If the students perceive that there is only one answer, there isn't as much need for the group. Surprisingly, Engineering is typically seen as solving ill-structured problems [1], but the students may not be picking up on that aspect of it.

B. The Challenge of Seeking Help

The literature on educational psychology has pointed out a paradox in students behaviors when choosing to seek help: If a student is confused, he may not want to seek help, perhaps to avoid admitting the confusion, a condition called *learned helplessness* [11]. Seeking and receiving help does lead to achievement, but students have to seek the help [12]. Quotes from the targeted questionnaire support the belief that the students may have felt that they were so confused that they could not ask for help.
"I haven't posted about questions because I am confident that my answers are wrong"
"I thought, I was the only one having problem understanding what was asked in the exam."
"who am I to post answers?"

Or, they may have felt that if they asked questions, they would be punished in the very competitive atmosphere.
"What was I suppose to do with it. Those who answered questions were severely criticised by [the teacher]."
"The overall environment for [this class] isn't a very help-oriented environment"

C. Faculty Attitudes and Models of Collaboration

One Civil Engineering faculty member, upon hearing about our results, responded, "But undergraduate students *should* have only single-answer problems! Design comes much later!" When posed the issue about ill-structured problems supporting collaboration better, he said that he didn't believe that collaboration was important, "But, oh yes, we got our ABET accreditation."

Faculty may not be as supportive of collaboration as the reformers and ABET seem to be. The attitude of the Computing teaching assistants is indicative of others whom we have talked to. If undergraduate learning is about learning facts and skills, then where is the role for collaboration? The research suggesting that collaboration may actually *improve* learning [11], even of rote facts [12], does not seem to be impacting this opinion.

If faculty are not supportive of collaboration, they may not convey to students what collaboration is about or how or why they should collaborate. Or even if the faculty are supportive, a traditional lecture-style class may not provide students with the models for what they are supposed to do in a collaborative learning situation. In classes where the CoWeb has been successful (e.g., Composition and Architecture) classes are organized around discussion. Engineering and Computer Science students told us in interviews that they didn't collaborate in the CoWeb because they simply didn't know what to do there. The students had no models for how to collaborate nor how to learn collaboratively (at least, with technology). Explicitly encouraging more discussion in class, including small group activities in class (or at least recitation), might help to provide models for collaborative learning.

V. What Can Be Done?

The experiences described in this paper—the failure of CoWebs to be used in Engineering, Mathematics, and some

Computer Science classes— lead naturally to the question of what can be done? Our analysis reveals three types of changes where the CoWeb (and tools like it) can be used to improve the situation.

First, the set of activities in which the students are asked to participate should be *scaffolded* and built around problems to which there is not necessarily "one right answer." Scaffolding is the process of guiding students through a process as they learn that process [13]. Collaboration and collaborative learning are themselves processes that students need help in learning [11]. Students should be shown the benefits of the collaboration, and the faculty themselves have to convey value of the CoWeb. While this typically means that the teacher should be visiting and posting to the class CoWeb, we have also seen value conveyed to the students by talking about the CoWeb and encouraging students to post to the CoWeb, e.g., "That's an excellent question—would you put it on the CoWeb for further discussion?" The collaborative activities should build explicitly on each other so that going back to earlier pages and editing them becomes a natural part of the students being in the CoWeb environment. The activities should focus less around solving specific problems or exercises with single answers and promote debate around problem formulation. The notion of the "right answer" should deliberately be placed subordinate to the definition of the problem and a diversity of definitions encouraged—with their concomitant answers.

The level of collaboration that the students are asked to participate in should also be raised during the course. For example, students might build confidence that they can collaborate with one or two other members of their class before they are asked to collaborate with students in a completely different year and major. The collaboration should be of low commitment—a single homework assignment, with the possibility of then changing the collaboration, followed by the formation of larger groups for more substantive assignments. The students should be encouraged to use the CoWeb to form these collaborations as well as pursue them.

Second, the surveys reveal several misconceptions that the students have about the CoWeb. These should be tackled head-on and explicitly. The most prevalent misconceptions amongst students appear to be the "one right answer" syndrome and the "fallacy of the curve." The CoWeb provides a medium for these misconceptions themselves to be discussed! If the class is graded on a curve, then evidence to the superior performance of those students who are active participants in the CoWeb could be used as evidence to bolster participation (with explicit debate on the nature of the cause-and-effect relationship encouraged.) A further misconception appears to be that the CoWeb will create more work—both for the students and for teaching assistants. Again, this should be debated, and the TAs involved in the discussion and the definition of the activities that take place in the CoWeb.

Finally, the CoWeb should be used to document an explicit model of how learning can be enhanced by its use, and the data that shows that students appear to have a richer learning experience and get more out of the class provided as part of the CoWeb. Surfacing the assumptions surrounding the tool and learning can provide a useful mechanism to improve its use and to defuse student apprehension about investing time in something whose reward may seem very intangible.

VI. Summary: Collaboration as an Important Challenge

Our results suggest that, if we believe collaboration is an important component of undergraduate education in Engineering, Mathematics, and Computer Science, there is a lot of work to do. Students see collaboration as not conducive to their success, and faculty may be agreeing with them. We need to change student and faculty attitudes, and perhaps some of our curriculum and the way we teach, too, if we want to encourage students to use collaboration in support of their learning.

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