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PROMOTING INTERACTION IN LARGE CLASSES WITH A COMPUTER-MEDIATED FEEDBACK SYSTEM

Abstract. Eliciting student participation in large college classes is notoriously difficult yet critical to learning. This paper describes a design experiment with a computer-mediated feedback system for promoting class interaction called the Classroom Feedback System (CFS). We delineate specific challenges to interaction and propose design principles to address them. CFS realizes these principles and establishes a computer-mediated channel for student-initiated feedback. Students position preset annotations (e.g., MORE EXPLANATION, GOT IT) directly on the lecture slides. CFS anonymizes the annotations and presents them to the instructor in real time. Successive experiments with paper and electronic prototypes validated our design and guided iterative refinement. Evidence from a large lecture study using the feedback system suggests that CFS increases levels of student-instructor interaction and addresses specific challenges to interaction.

1 INTRODUCTION

Student-instructor interaction is vital to student learning. However, soliciting student feedback in large, university-level lecture classes (with about 50 students or more) is challenging; as a result, lectures tend to lack interaction [Bligh, 2000]. Yet, as educational institutions serve more students and face tighter resource constraints, the large lecture is likely to persist, especially at the introductory level, creating a need for innovative approaches to large class challenges.

We have designed a feedback system to address this problem. We began by identifying challenges to interaction in large classes by reviewing existing literature and observing courses. Based on these challenges, we designed the Classroom Feedback System (CFS), a computer-mediated feedback system to promote student-initiated interaction. (See overview in Figure 1.) Students view lecture slides on the classroom display and on their wireless devices, and the instructor controls the presentation from her own device. Students can annotate any point on a slide with feedback from a preset list selected by the instructor (e.g., MORE EXPLANATION, GOT IT). CFS anonymizes feedback before displaying it to the instructor within slide context. CFS differs from existing audience-initiated feedback systems by providing rich context: merging comments with slide context to aid the students in crafting meaningful feedback and the instructor in interpreting that feedback. CFS is novel in empowering students to provide simple yet descriptive feedback on their own initiative.

Following design experiment methodology [Brown, 1992], we began by studying our target setting, large university-level classes, through observations. Next, we experimented with a paper prototype of the feedback system; students annotated paper slides with free text and category comments. These initial experiments led to an understanding of the domain and design principles for our system. We performed a pilot study with a pen-and-paper and an electronic prototype of the system in a large class. Our pilot study confirmed that students have feedback to give, they are willing to provide it through an electronic medium, and an instructor can respond effectively to this feedback, changing her pace and explaining confusing concepts. Finally, we engineered a learning environment using the full-featured CFS in an introductory pro-

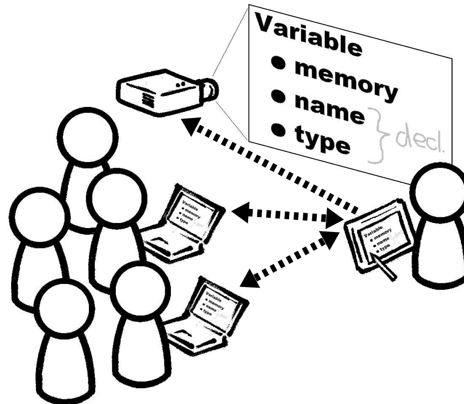

Figure 1: Overview of system setup, consisting of the instructor's device, students' devices, and a projector for the classroom display. Dotted arrows represent wireless transfer of the presentation and feedback.

gramming course. This paper reports how the system addressed interaction challenges in this most recent experiment.

The paper structure reflects our principal contributions: (1) a set of challenges associated with interaction in large classes, (2) design of a feedback system to address these challenges, and (3) experimental results demonstrating CFS's success in promoting interaction in a large class and exploring its relationship to the challenges.

2 CHALLENGES TO INTERACTION IN LARGE CLASSES

The education community has long discussed the challenges of facilitating student-instructor interaction in large classes [Geske, 1992, Gleason, 1986]. This work focuses on the lack of student-initiated interaction in large lectures. This lack poses a serious threat to the learning environment because interaction is important to student learning [McKeachie, 1990]. Based on literature and experiments with prototypes of CFS, we have identified several primary factors inhibiting student-initiated interaction in large classes: feedback lag, student apprehension, comment verbalization, and the single-speaker paradigm.

Feedback Lag: A fast-paced lecture can leave inadequate time for the student to process presented material [Bligh, 2000], let alone interrupt with a question, reducing student participation. This problem was reflected in our pilot study. Students in the study were unsure of the value of their questions on a topic until the topic was finished. Then, when the lecture moved on, they believed the "window of opportunity" to ask their questions had passed.

Student Apprehension: Students are intimidated by the number of students in large classes [Bowers, 1986]. They will remain silent rather than interrupt class to ask a question they perceive as stupid or unimportant. In our pilot study, 6 of the 12 participants reported apprehension as a factor limiting their participation, e.g.: "Didn't want to sound incompetent".

Comment Verbalization: Instructors of large classes in our department have often observed that students have trouble communicating their confusion in words.

Single-speaker Paradigm: Large classes can sustain only limited time for spoken

feedback. When one student speaks to the instructor to ask a question or make a comment, no one else in the class can speak, and the instructor's attention focuses on that one student. This "single-speaker paradigm" limits the potential for student participation. In our pilot study, 3 of 12 participants reported class size as a factor limiting participation, e.g.: "too many people."

We believe that these challenges to participation represent the core obstacles to interaction in the large lecture classroom.

3 DESIGNED SYSTEM

In response to the challenges faced by large lecture classes, we designed a technological system to promote interaction called the Classroom Feedback System (CFS). The increasing presence of technology in the classroom offers affordances that make this system possible: many college classrooms have data projectors and computers to drive them, high bandwidth wireless networking is becoming more common in classrooms; as a result, many instructors use prepared slides to mediate their presentations. We assumed these affordances in designing CFS and leveraged them to address the challenges from Section 2. Our set of central design principles establishes the connection among challenges, affordances, and implementation:

Non-verbal communication: Networked computers provide an alternative to speech, sidestepping the single-speaker problem. Many students can simultaneously interact through individual computers sharing a network.

Anonymity: Anonymity helps to address the challenge of student apprehension. Anonymizing student feedback in a computer-mediated system is simple and rapid.

Shared context for feedback: Prepared slides can form a context for feedback, with students attaching comments to items on the slide. This scaffolds comment verbalization by exploiting a mediating artifact to which instructors and students already attend. The potential to annotate past slides would also address feedback lag, allowing students to pose questions in context even after discussion has moved on.

Rapid, automatic synthesis of feedback: Although we do not emphasize this for the current, small-scale studies, aggregating feedback for the instructor will become crucial as the number of students and therefore the amount of feedback scales up.

Closure: The instructor in our pilot study requested that students be able to remove existing feedback to indicate that she had addressed it. Augmenting or modifying feedback allows this kind of closure.

Simple Interfaces: Students and instructors are engaged in classroom activities; therefore, the system should demand few cognitive resources for the feedback task.

Using these principles as a guide, we implemented CFS. It is built atop presentation software allowing the instructor to navigate through and write on a slide-based presentation from a Tablet PC [Anderson et al., 2003]. CFS is composed of a student view (on student devices), instructor view (on the instructor's private device), and shared view (slides displayed to the entire class as in "normal" presentations).

CFS uses wirelessly networked laptops as student devices. Each student view (see Figure 2(a)) displays the current and previously visited slide with the student's feedback superimposed. Both slides are displayed on students' devices to address feedback lag. Students generate feedback from a fixed list of possible annotations by right-clicking and then selecting a category from a menu. This feedback is sent to the instructor's device. If a student decides his feedback has been addressed, a click on

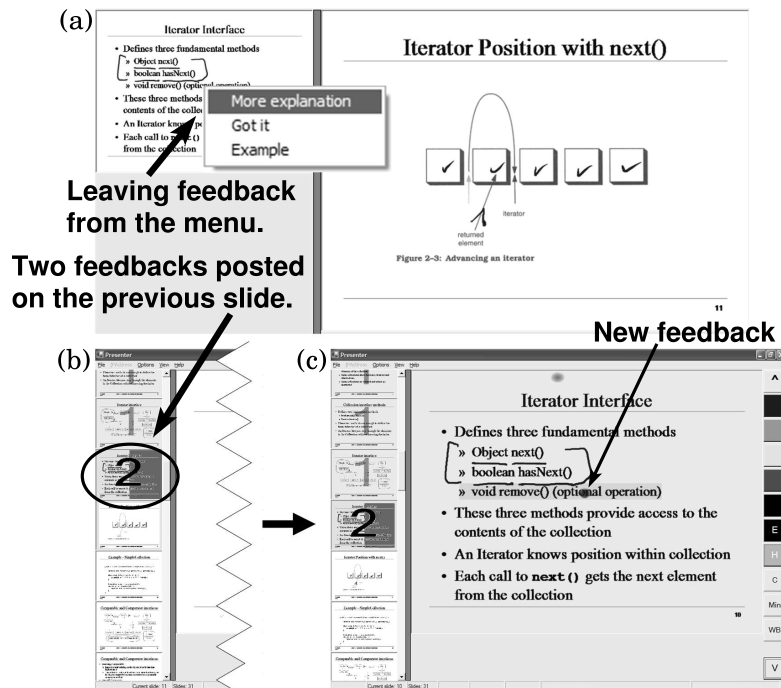

Figure 2: Views of the student (a) and instructor (b, c) interfaces of CFS. In (a), the student is posting a MORE EXPLANATION *annotation on the last slide visited. (b) is cropped from the left side of the instructor's view: the student's feedback has just combined with existing feedback to yield a count of two annotations (with color encoding the categories) on the thumbnail of the previous slide. In (c), the instructor has transitioned back to the slide with the feedback. The new feedback is a small circle on the word "optional." Another student's feedback (color-coded as* GOT IT*) is at the top of the slide. These slides and feedback are taken from the logs of an episode that occurred in the study class which is detailed in Section 5.*

the feedback removes it. Using a small set of categories keeps the interface simple, and supporting annotation on the slide leverages shared context.

The instructor controls the presentation from the instructor view (see Figure 2(c)). This view shows aggregated feedback through two mechanisms: each student's annotation is represented by a colored translucent circle according to the entered position by the student and all annotations on a slide region are further aggregated into a highlight on that region. The colored circles indicate categorical information (e.g. red for MORE EXPLANATION) and slide context while keeping the instructor view uncluttered. To preserve anonymity, no identifying information is associated with the annotations. The instructor's filmstrip view of the slide deck (on the left in the figure) summarizes feedback on other slides.

A key parameter is the set of feedback categories. We suggest that they be important to the course, be few in number, share thematic similarities (as a mnemonic), and include at least one option for positive feedback. This last was inspired by students' fervent desire for and extensive use of a positive feedback category in our pilot study.

We envision students using CFS to express their confusion or interest. The instructor monitors her view peripherally and chooses when to respond to feedback she

considers important. She might also set time aside for feedback on some slides. Other uses include improving slides from term to term based on archived feedback, designing feedback opportunities as part of classroom assessment activites, using feedback to support voting, or refining upcoming lectures based on feedback in current ones.

4 IN-CLASS FEEDBACK EXPERIMENT

We ran an experiment with the prototype system in a large university-level introductory programming class in order to understand how a real class would use and adapt to CFS. During the experiment, we focused on understanding what interaction occurred and how it changed in response to CFS.

The course started with an approximate enrollment of 150 and ended with 120. Students attended three 50-minute lectures weekly during a nine-week academic term. In order to compare interaction behavior with and without the system, CFS was used only during seven class meetings spanning the last three weeks of the term. 12 student volunteers participated in the study. We supplied each student with a laptop computer for in-class use. On average, 8 of the 12 students picked up their laptops each lecture. (Attendance was spotty as in many large classes.)

We met with students prior to their use of CFS to familiarize them with the technology and to assign each a unique ID number. We met with the instructor (who was not a member of the research team) regularly to get his opinions about the class and CFS. We negotiated feedback categories with the instructor and students. They settled on three categories: MORE EXPLANATION requests elaboration of a topic, EXAMPLE requests an illustrative example of a topic, and GOT IT indicates that the student understands a topic.

We collected a variety of qualitative and quantitative data in an effort to "triangulate" interesting phenomena. The data sources are explained below with the names by which we refer to them italicized. We collected *meeting notes* during all meetings with participants. Two researchers recorded their *observations* (137 handwritten pages total) at each class meeting from five minutes before until ten minutes after class, identifying students by ID where possible. We collected all class handouts. CFS recorded *logs* of all navigation, writing, and feedback annotation and removal (both tagged by ID). We asked the 12 volunteers to complete a long *survey* with responses identified by ID (11 completed it). We put a brief, *class-wide survey* on the course evaluations (42 completed it). We collected publicly available *course evalution* data. At the end of the term, we interviewed the instructor and transcribed the audio recording of the *interview* (2000 lines of typewritten data).

5 ANALYSIS

A number of interesting themes emerged from our data. Among these were: the success of the simple user interface contrasted with student difficulties with the laptops' form factor, and intriguing patterns of interaction—several unique to CFS. However, because of space restrictions, we focus on CFS's impact on the amount of interaction in the class and how the system (and our design principles in particular) addressed the current challenges to interaction. To familiarize the reader with CFS's use, we first briefly detail one episode of interaction and give a sense of the classroom environment.

Our illustrative episode took place on the seventh and last day of system use. Our observations show that a student raised her hand to ask a question but was not seen by the instructor. After about a minute, the instructor transitioned to the next slide, and the student abandoned asking the question aloud. Instead, the student annotated the previous slide with MORE EXPLANATION (Figure 2(a)). The instructor looked at his screen about four seconds later—the log records his interaction with CFS's interface at this time—and so probably noticed the annotation then. Figure 2(b) shows how the feedback was reflected in the filmstrip view. The instructor continued his discussion of the current slide for 40 seconds—perhaps waiting for a comfortable breaking point—before transitioning back to the annotated slide (Figure 2(c)). The instructor then assessed and responded to the student's feedback. Although the student did not then remove her feedback, she related an episode that was most likely the same one in which the instructor responded effectively to her feedback: "I think I asked for more explanation of a given word and he explained well. It was even on a slide that he had already passed by."

Lecture usually proceeded as follows: the instructor begins with administrative announcements, then often asks for and fields questions, and finally, begins his prepared lecture. The instructor used computer-projected materials exclusively (slides, program demonstrations, course web pages), and switched between these media an average of 7 times per lecture. He generally adhered to a sequential presentation of his slides, and was almost always able to cover all slides he prepared for the lecture (20 on average). Spoken student participation was limited as shown in Table 1. Overall student perception of the class was positive: course evaluations were slightly higher than the same course in previous quarters.

5.1 Effect on interaction

CFS was successful in promoting interaction. Students provided a large quantity of feedback through CFS. As Table 1 shows, there was a statistically significant and substantial increase in student input with the system. Discounting GOT ITs (which rarely initiated interactions), the change is not statistically significant but still suggestive of increased interaction, considering that only one in ten students in class used the system while all could contribute aloud.

The instructor felt the student feedback—with the exception of GOT ITs merited response in class. He felt that ignoring a feedback comment was as egregious as ignoring a spoken question. In response to the suggestion of skipping such comments, he said: "No, ... if they raised their hand, I would answer the question." 7 of 11 students in the survey believed the instructor responded to almost all of their feedback. At the same time, CFS did not seem to hinder traditional interactions. As shown in Table 1, the number of student voicings before CFS and during its use were consistent with each other. Our data suggests that broader adoption of CFS would not disrupt traditional participation. We did observe students with laptops participating aloud in class. All 11 students in the survey felt that they were no more or less comfortable participating aloud while using CFS, and 10 of the 11 felt that their level of spoken participation was unchanged by CFS.[1]

[1]The student who reported a reduced level of spoken participation reported more than three spoken interactions per class before CFS and none with it. That prior level of input was probably erroneous as it would account for all voicings in the class.

*Table 1: Comparison of student input before using CFS (15 classes) to various measures of student input during its use (7 classes). Voicings are spoken student comments or questions. "Feedback" is the number of feedback annotations, discounting mistaken annotations and counting multiple annotations expressing a single idea as one. "Non-*GOT IT *feedback" further discounts all* GOT IT *annotations. All significance tests are heteroscedastic, two-tailed t-tests with significance at the* $p = .1$ *level. The starred column is significant.*

	Voicings pre-CFS	Voicings with CFS	Voicings + feedback	Voicings + non-GOT IT feedback
# per class	2.4	2.6	**15.9***	7.9
p-value	——	.91	**.04***	.14

5.2 Addressing Challenges to Interaction

The data from the use of CFS suggests that some interaction challenges were addressed by use of the system while others interacted in surprising ways with system design choices and the classroom climate. Overall, satisfaction with CFS correlated strongly with students' perception of difficulties interacting in class. 8 of 11 students surveyed reported that factors in class inhibited them from participating aloud. The same 8 students reported that they enjoyed using the system while the other 3 reported that they did not. In the remainder of this section, we discuss each challenge and how its manifestation in class changed with CFS.

Feedback Lag: Feedback lag was a prominent problem before CFS. This challenge manifested itself as a lack of opportunities for students to interject comments and questions. The instructor explicity asked for questions only 16 times over 22 observed lectures, but students had a sense that *un*solicited questions would interrupt the flow of lecture. 3 of 11 students surveyed reported an aversion to disrupting the flow, e.g., one student cited: "Difficulty finding an opening or break to ask questions. Not wanting to slow class down." The instructor seemed open to immediately relevant questions, but also stated: "I write the slides with the idea that there's a narrative, and it's really painful to keep interrupting that and go back."

CFS proved valuable to students in addressing feedback lag. Of the 3 students who cited feedback lag as an impediment to spoken participation, only 1 mentioned it as an impediment to feedback through CFS. CFS seems to have helped address feedback lag for that one student as well. As he put it: "With the system in place, it became much easier to ask the professor to explain a topic more or give an example while minimizing the interruption to the class."

Two distinct strategies for overcoming feedback lag with CFS emerged. Two students reported that they used the strategy we had expected: waiting until the instructor had finished discussing a point or slide before annotating it. We were surprised to discover that students also overcame feedback lag by annotating *ahead* of the lecture, on points that the instructor had not yet discussed. Many instructors have identified this premature annotation as a potential problem when trying CFS out. However, CFS's private student-instructor channel and the persistence of annotations seem to render this behavior acceptable. In one case, for example, two students asked for more explanation of a bullet while the instructor was still discussing earlier bullets. When the instructor reached the bullet in question a minute after the annotations appeared, he gave it special attention. Soon, both students annotated the bullet with GOT ITs. In

the interview, the instructor described this pattern of student-guided elaboration of the slide as a particularly effective and non-intrusive use of CFS. The episode described at the beginning of Section 5 also illustrates how CFS helped to overcome feedback lag.

Two students who did not report suffering feedback lag with spoken questions reported suffering it with CFS. Because of the speed with which the instructor sometimes covered slides, the students sometimes did not have time to annotate the previous slide before it was replaced. Broader navigational capabilities might address these students concerns.

Student Apprehension: Students felt apprehensive about speaking in class. 6 of 11 students surveyed cited inhibiting factors such as "nervousness" and "larger class size." Some evidence suggests that CFS helped to address student apprehension. None of the 6 students mentioned apprehension as limiting their participation through CFS. Only 1 student mentioned apprehension as a limiting factor in CFS at all. That student wrote: "if I were more concerned with what the other students thought of me, I would have been wary of having the students behind me notice my mouse click..." This insight is a reminder that the "guarantees" of anonymity we build into computer systems may not protect users' identities in real environments. Still, this student was not personally apprehensive. Two specific episodes in class reinforce this disparity of apprehension between CFS and spoken participation. In each one, the instructor tried and failed to elicit spoken participation by a student who had given feedback. Neither feedback lag nor the single-speaker paradigm adequately explains the student's reticence to respond as there was an express opening to speak. Apprehension is a likely explanation, especially since the student who made both feedback annotations was one of those who cited nervousness as an an inhibiting factor in the survey.

Although anonymity helped address apprehension, it also created significant obstacles to the instructor's understanding of feedback, sometimes because he could not see correlation of feedback (i.e., which of multiple comments came from the same student), and sometimes because he could not see the specific identity of students giving feedback. As an example of the correlation problem, one student annotated three Java classes out of a set of six with MORE EXPLANATIONS to indicate which ones confused him. With no knowledge that these distinct annotations came from the same student, the instructor had difficulty interpreting them as expressing a single concept. Also, he was unable to judge how many students were, in fact, confused. The instructor actually requested correlation of feedback, saying: "I want to know that one person [as opposed to several] wants some more information about the slide." The one mechanism that *was* correlated, removing feedback, met with approbation from the instructor: "...if I could see that the screen had gone clean [of feedback annotations] again, I think that makes sense." Not knowing students' identities meant that the instructor could not evaluate feedback with respect to his knowledge of the student who gave it (as he did with spoken feedback). The instructor also was unable to follow up on feedback outside of class (as he sometimes did with spoken feedback).

Comment Verbalization: A small amount of evidence that CFS helped to address articulation emerged from the data. Communication of issues through CFS were often resolved. About 1 in every 3 non-GOT IT annotations was either cleared or marked with GOT IT to indicate it had been addressed. These and perhaps other feedback were successfully answered. On the other hand, only 3 of the 11 students surveyed

found the feedback categories sufficient to express their feedback while 6 others requested the ability to type in their own questions or comments, suggesting difficulty in articulating their questions through placement and the existing categories. The instructor, for his part, found interpreting the EXAMPLE feedback straightforward but expressed difficulty in interpreting MORE EXPLANATION and GOT IT. The instructor frequently did respond to MORE EXPLANATION; however, he lacked confidence in his interpretation of the feedback, saying: "I never really did get a good solid feeling for the kind of conversation I was able to have with people as a result of [More explanation feedback]. ... It was really hard to tell whether I was addressing the issue or not."

Single-speaker Paradigm: In a technical sense, the single-speaker paradigm is no longer a problem in CFS: multiple students *can* express themselves at the same time. In practice, a new issue arises: whether the instructor can manage *many* "speakers." During one heavy period of feedback with 7 annotations by 4 different students on a single slide, neither observer was aware that the instructor was responding to feedback[2], despite specifically watching for evidence of interactions and the effects of CFS. However, the instructor was quite flustered by this episode, describing himself as "apparently having had some sort of brain seizure" while responding to the feedback. With more students and more feedback, this problem could escalate. Further research will show whether aggregation techniques and practice will allow instructors to cope with the "multi-speaker paradigm."

6 RELATED WORK

Our system builds on prior efforts in supporting classroom interaction but is unique in accommodating student-initiated feedback in a rich, shared context and requiring little instructor effort for adoption. (See [VanDeGrift et al., 2002] for a more extensive discussion of related work.) Some existing classroom technologies (e.g., [Dufresne et al., 1996]) support instructor-initiated input opportunities like CATs or quizzes. Brittain's work with mobile phones [Brittain, 2001] was inspirational for our work, but this and other student-initiated feedback systems provide minimal context for feedback. ActiveClass [Griswold et al., 2002] supports both instructor- and student-initiated interaction. While ActiveClass lacks the rich context for feedback we provide, it offers an innovative solution to the tradeoff between a small number of feedback categories (survey responses, in their case) and flexibility by allowing students to enter new categories which can then be used by other students.

7 CONCLUSIONS

We have described the design of the Classroom Feedback System (CFS), a system for promoting interaction in large classes. Through the design and deployment of the computer-mediated feedback system, we successfully engineered a more interactive learning environment with a new medium for student-instructor interaction. In the process, we identified key challenges to interaction and grounded these challenges in literature, discussions with instructors, and data from large classes. Analysis of an experiment with our designed system demonstrated its success in promoting

[2] At the time, the observers saw only the shared view; later, they could "peek" at the instructor's view.

interaction and revealed interesting interplay with the challenges we identified.

Although this work shows the value of contextual feedback, it also suggests new ways to address the challenges we identified. Mollifying our strict anonymity policy to reveal correlations among feedback or even reveal students' identities (to the instructor alone) might reduce difficulties interpreting the meaning of multiple feedback annotations and enable new interactions. Allowing extra categories (as ActiveClass does [Griswold et al., 2002]) or supporting free text might help students express themselves and provide extra confidence to instructors in their interpretation of feedback. Displaying extra information about a comment on mouseover would be one mechanism to address all of these extensions: popping up associated freeform text, highlighting correlated feedback annotations, and revealing the identity of the student that gave a comment. Allowing the instructor, like students, to modify feedback would enable in-system mechanisms for following up questions (as the instructor in our study requested). Future experiments should investigate such promising directions and also study the effect of broader adoption with more students in a single class and with a wide variety of courses.

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