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THE ACTIVECLASS PROJECT: EXPERIMENTS IN ENCOURAGING CLASSROOM PARTICIPATION

Abstract. Participation in the classroom has dropped precipitously in recent years. We describe the use of ActiveClass, an application for encouraging in-class participation using personal wireless devices. This system was used in three sections of two different lower division courses in computer programming at UCSD. Using a notion of *ecology* to develop our method of analysis, these settings provide a rich source of insight into technology-mediated learning and student activity. We find that a broadening of classroom discourse is possible if attention is paid to both political and material forces present in the classroom.

1. INTRODUCTION

University professors have noted a precipitous drop in participation in the classroom. With a growing number of unasked questions, a professor's lecture may grow increasingly senseless to students. At the same time, without interaction, inferior passive learning modes emerge. One theory is that increased diversity and growing class size have created classroom dynamics that discourage participation. For some, asking a question may be challenging authority or simply impolite. For others, the prospect of embarrassing oneself in front of fellow students is too much to bear in such an impersonal setting. Some fear that they will hold up the class (i.e., a huge number of people) with their personal question.

Classrooms, like other parts of the educational infrastructure, have evolved to accommodate a large number of people, employing stadium seating, microphones, and LCD projectors. These changes do not address the social dynamics of a large, diverse classroom of students. To fill this gap, we developed ActiveClass (available at http://activecampus.ucsd.edu), a simple client–server application for enhancing participation in the classroom setting via small mobile wireless devices such as Personal Digital Assistants (PDA's). ActiveClass is intentionally minimal in both its function and requirements for integration into classroom practice. The former permits students to use low-cost mobile devices, the latter eases adoption by the institution and professors. The basic idea behind ActiveClass is simple: using personal, mobile wireless computing devices, students can anonymously ask questions, answer polls, and give the professor feedback on the class (Truong et al., 2002). Every student and the professor see these lists of questions, poll results, etc. Furthermore, students can vote on previously asked questions. This raises their ranking in the display, encouraging the professor to give those questions precedence.

A number of researchers have been exploring the possibility of mobile wireless technologies to enhance the classroom environment. Gay et al. report on the impact

To Appear in Computer Support for Collaborative Learning 2003

of basic wireless networking in the classroom environment (Gay et al., 2001). Classtalk focuses on giving lecturers the ability to pose questions to students (Dufresne et al., 1996). These features are similar to, but more general than, our polling features. The eClass project (formerly Classroom 2000) provides facilities for structured capture and access of classroom lecture activities (Abowd, 1999). Anderson et al. survey the barriers to classroom participation, and describe how student-initiated feedback through computer-mediated contextual structured interaction can lower these barriers (Anderson et al., 2003).

This paper focuses on the use of personal wireless devices and ActiveClass's student question-asking feature, providing several insights into mobile technology for encouraging classroom participation. To begin, we found it difficult to understand ActiveClass's role in the classroom by studying participation alone. In particular, we found that a number of distinct and interacting dynamics were constituting a continually evolving classroom practice. To make sense of these multiple interacting dynamics, we adopted an *ecological* view (Hughes, 1971; Star, 1995; Fujimura, 1995) of the classroom and beyond. Using ecologies it was possible to see, despite the professor's and students' shared desires for classroom participation, that these two parties (as well as the teaching assistants and the researchers) in fact had widely differing requirements for the use of ActiveClass in the classroom. Moreover, both the material (i.e., physical) constitution of the setting and circumstances beyond the classroom provided a significant influence on that dynamic. We observe also that, like the shearing layers of building architecture (Brand, 1995, Ch. 2), the competitive ecology drives change at a different rate within each of these aspects, sometimes reducing surprising consequences.

From this perspective, ActiveClass changed the ecology of the classroom setting in several distinct ways. For example, its thin veil of anonymity resulted in a broader range of questions, yet gave the professor the ability to choose among those questions rather than picking students with raised hands. Ecologically, ActiveClass can be seen as producing a question-fitness gradient that is based on the question's fitness rather than the assertiveness of the student (raises hand first) and the professor's perceived fitness of the student for asking questions (asked good questions in the last). To achieve this sustainable balance, however, ActiveClass had to be successively adapted to meet everyone's needs and expectations. The slow-changing material dimension of the classroom ecology significantly mediated this dynamic. For example, students left their PDA's home for fear of breaking them, forgot to recharge them, and their small classroom desks complicated integrating their use with traditional notetaking. Fundamentally, we found that ActiveClass was perhaps not addressing issues of shyness, but rather was broadening discourse. In particular, there was no evidence that more people (i.e., shy people) were asking questions. Now we are investigating the hypothesis that people disinclined to participate are also less likely to experiment with technology, at least in the (public) classroom setting. Although the failure to gain the participation of disenfranchised students is a failure, the broadening of discourse is a significant gain.

The rest of this paper is organized as follows. In the next section we introduce our setting and a typical classroom scenario that includes the use of ActiveClass. We then introduce ecologies as a conceptual framework for understanding our setting,

followed by an analysis of the two major facets—politics and materiality—that contribute to the overall ecology. The paper closes with a brief conclusion.

2. ACTIVECLASS: SETTING AND USE

By way of a scenario, we introduce ActiveClass and the modes of interaction we found it to support in CSE 12 and 30. Although this scenario was constructed for illustrative purposes, all the examples here are based on actual data and experiences during the experiment. After the scenario, we will briefly discuss other details of the classroom experience not captured in the scenario. Subsequent sections will describe the concepts behind ActiveClass's design and how it supports these interactions. Below and in the rest of the paper, we will refer to ActiveClass's users as *admins* and *users*. An admin might be the professor, one of his or her teaching assistants (TA's), or a designated student. Users are students. ActiveClass being a web application, we often refer to its features as *pages*.

2.1. Setting

UCSD operates on the quarter system, with 10 weeks of classes and 1 week of finals per quarter. CSE 12 and 30 are the second and third courses in computer programming. Difficult topics such as recursion and pointers are taught in considerable detail, and there are several programming assignments. Professor G., a lecturer, taught two sections of CSE 12 back-to-back, the first with 150 students, the second with 75. Professor O., also a lecturer, taught CSE 30 to a class of about 125 students. The classes met Tuesday–Thursday. The classes were diverse, including both majors and non-majors, freshmen and transfer students, etc. The rooms were similar for all sections: stadium-style seating and a bright projector that does not require the lights to be turned off. In the following scenario, we focus on Professor G.; for the purposes of this paper Professor O.'s behavior was not significantly different. Professor G. teaches from overhead transparencies. His style is to lecture for a stretch and then take questions. He uses lots of examples. Professor G. and his course are quite popular. He is dedicated and he maintains an avid crew of undergraduate teaching assistants (called tutors at UCSD) who have previously taken the course. A threaded discussion board is used for students and tutors to share information outside of class; it is mostly, but not entirely, used for programming assignments. ActiveClass went into use three weeks into the term, after all student drop/adds were complete and all students had a chance to attend a meeting to receive a Jornada 548 PDA, hear about the project, and try out ActiveClass.

2.2. Scenario

Sim walks into CSE 12 a few minutes before class, pulls out her wireless PDA, logs in to the ActiveClass server, and chooses the CSE 12 session. The class's Information page comes up with notes about the last lecture and ancillary material.

At about the same time Professor G. enters the room, pulls out his overhead slides and boots his laptop. He logs into ActiveClass and navigates to the admin's questions page, which summarizes the questions from the class session and refreshes every 30 seconds. Now if he wants to take questions during class, he can quickly have a look at his laptop to see what's going on. One of his TA's has also logged in as an admin and will actively monitor the session.

Professor G. begins his lecture, explaining how hashtables are a fast way to search. He stops occasionally for questions, but he gets little response.

Sim's lost. She doesn't understand why the program doesn't need to search the whole table for an element. Because nobody else seems to be lost, she doesn't want to raise her hand. Maybe Prof. G. already answered her question and she missed it while taking notes. Knowing that the midterm is coming soon, she decides she'd better ask her question through ActiveClass. Soon after asking the question she notices that many students are voting for it, and it rises to the top of the list.

Professor G. knows that at least a few students must be lost. He says, "Let's see if the virtual student has any questions," switching his attention from his overheads to ActiveClass. Looking at the top-ranked question, he realizes they've missed a key concept. He draws on the students' recent homework experience with sorting to convey how keys relate to the placement of elements, and how that can help find an element quickly. He then reviews how hashing achieves the same goal without the cost of sorting. Students start raising their hands with follow-up questions. As the discussion concludes, Professor G. hides the question to reduce clutter in the view.

Sim is relieved to have had her question answered. She returns to ActiveClass and resorts the questions in chronological order with the newest ones at the top. She notices that the TA answered a question about the due date of homework 4.

Now that class is over, Professor G. uses the Save to Warehouse feature on the Session page to capture today's questions. Thinking that one question was especially good, he goes to the Spy page. It lists all the questions and answers that students have entered. He clicks on the question to see who asked it, seeing that it is Sim. He makes a mental note to speak to her some time.

3. THE CLASSROOM ECOLOGY

3.1. The Ecological Perspective

At the beginning of our investigations, much of our analytic focus was directed towards the technical details of the ActiveClass software and the personal experiences of individuals who used or did not use it. However, we soon found that this narrow focus did little to help us explain the practices that actually emerged within the classroom and the extent to which students participated in them.

To widen our unit of analysis we drew upon the notion of *ecology*. Hughes originally used the term to describe the complex and emergent play of forces that occurs when members of different social worlds try and accomplish tasks despite having different conceptions of what those tasks involve (Hughes, 1971). Star extends the term to include a focus on the categories as well as the units of analysis,

saying "Thus by ecological we mean refusing social/natural or social/technical dichotomies and inventing systematic and dialectical units of analysis" (Star, 1995, p. 2). Actor-network theory (Callon and Law, 1989) also treats social and technical aspects using similar terms, but tends to emphasize the individual actions that 'enroll' new members into a network (Law and Hassard, 1999). We follow Fujimura in focusing instead on the "...linking of practices, work routines, and theory in diverse situations" (Fujimura, 1995, p. 304) that together constantly construct and reconstruct the situations we study. This view shares much with the notion of situated action (Suchman, 1987), but differs due to our explicit focus on the relationship between the political (i.e. social relations), the ideal, and the material.

Three features of the ecological notion were particularly helpful in understanding the complex classroom setting. First, thinking of the classroom as an ecology reminded us of the complexly interwoven physical, conceptual, social, and technical aspects that formed the classroom experience. An ecological perspective redirected us to examine such seemingly mundane things as the physical layout of the classroom, the shape of student desks, and the many other artifacts and relationships that informed this space. Moreover, we were led to examine activities beyond the classroom by Hughes's admonition that "...while any human phenomenon is worth studying closely, if at all, it is never to be completely understood in terms of itself. Its peripheries must be explored" (Hughes, 1971, preface).

Although we recognized the importance of the complex and in some ways unbounded nature of ActiveClass, a key problem was how to meaningfully relate the different aspects we were discovering. For this we borrowed a concept from architecture, popularized by Brand (Brand, 1995, Ch. 2). Brand describes how buildings, seemingly stable and unchanging, are actually adapted to their inhabitants over time. According to Brand, these processes of adaptation are often hindered by architects who fail to design buildings with this fact in mind. Brand sets out the notion that different physical layers (i.e., aspects) of buildings (which he describes as the 6 S's) respond to change at unequal rates. The 'site'—physical location of a building—is the most resistant to change, while the 'stuff' within the building is the most open to change and reorganization. Other aspects of a building are its 'space plan' or internal layout, its 'services' such as heating and power, its 'skin' or external facade, and its 'structure' or fundamental supporting frame. Each of these is adaptable to user needs at different rates, based, in part, on the expense and trouble to modify. It is possible for many of these aspects to be interwoven: the services of a building may be embedded within its facade, making change to one impossible without change to the other. Brand's design advice—to keep the different layers of buildings separate in order to encourage adaptation and change—applies to the classroom setting as well. Thus, examining the multiple aspects of the ActiveClass project, grouping them together, and relating these groups to each other based on the differential rates of change is an important methodological concept for our work.

Based on these features of the ecological metaphor we developed three methodological principles. First, aspectization—to uncover and describe the multiple aspects of the classroom ecology. Second, aspect interrelation—to note the differing rates of change of these aspects and to differentiate them based on this. Third is predictability–to examine these ecological arrangements to understand how

they all worked together in order to create or undermine predictability within the ecology (e.g., how the class will be run). We should note here that predictability is not an inherent state of an ecology, but is created by participants as they work to advance their own ends. This is a key part of our notion of ecology, namely that aspects of ecologies exist together, but are separate—separate in terms of the time scale at which they adapt or are adapted, as well as who has the right, responsibility, or possibility of determining that change or stopping it from happening.

The ActiveCampus PDAs were introduced into a space possessing considerable social, physical, and technological complexity. Students adopting ActiveClass are required to integrate it into this environment by adopting work practices that allow their PDAs to work in concert with the physical setting of the class, the personal artifacts that are already included in students' class-going regime, and the technical challenges of managing computer systems.

In the next two subsections, we address two aspects within the classroom ecology. These are what we have termed the political aspects (i.e., the relations between professor and students) and the physical aspects (the desks, artifacts, and layout of the classroom.) These two aspects can be likened to the different layers of Brand's buildings. Due to the differing rates of change of each aspect, they have qualitatively different effects on classroom practice.

3.2. The Political Aspect

Before the study began, Professor G. cited many concerns about ActiveClass. One was the broad-brush anonymity of the system. We compromised, giving him a feature that let him "inspect" a question for its author (providing a thin veil of anonymity), while maintaining complete anonymity among the students.

Two, he was concerned that ActiveClass would unacceptably complicate his routine, as it would be yet another thing for him to manage during class. However, by using a TA to monitor the session for appropriate use and the like, he was free to ignore ActiveClass until his usual breaks for questions. During these breaks, he took to calling his laptop "the virtual student". This metaphor for his ActiveClass session had two benefits. For him, it meant that his laptop was just one more student asking questions. He would usually refer to ActiveClass only after taking direct questions from students raising their hands, signalling that he preferred that students participate verbally. For the students, it meant that any apparent negative reaction to a question from ActiveClass would be absorbed by the virtual student, and no aspersions would be cast on the students. Taken together, the metaphor indicates the professor wished to construct a positive atmosphere for active participation.

A few other behaviors point to the possible benefits of ActiveClass. More than once the professor used ActiveClass to carry classroom activity beyond the bounds of the 80 minute lecture. He did three things. One, he carried particularly good questions from his first section to his second section of the class. Two, he carried unanswered questions from the end of one class meeting to the beginning of the next one. Three, he moved a particularly rich question offline into the discussion forum; that is, the professor used the saved state of ActiveClass as a memory aid between

the class time and the time he got around to moving the question to the forum. In short, ActiveClass was impacting the boundaries of the ecology.

An interesting tendency among the students and the TAs was to use both the question and answer features as affordances for communication. Indeed, we added the Answer Question feature because we observed students sometimes answered questions by using the Ask Question feature. Once the Answer Question feature was added, students sometimes used it to thank those who provided answers. Also, a TA would sometimes use it to answer questions that were off topic, thus helping a student while keeping the professor and the rest of the class on topic.

A few data points give a feel for ActiveClass's role in the classroom. After the novelty of ActiveClass wore off, about a third of students provided some kind of input (question, vote, etc.) to ActiveClass on a regular basis. In CSE 12, the average number of questions asked per class session was 8, and on average 40 votes were cast per class session. These numbers were slightly lower in CSE 30, where the professor's lecture style was more interactive. Once the answer feature was introduced, essentially every question that was not directed specifically at the professor was answered by another student, with a maximum of 8 different answers for a question.

Although participation may seem low, the professor carried over good questions to his second section, reducing the need for entering additional questions in the second class. Also, by our judgment—and that of the professor—the level of the questions was quite high and qualitatively different than seen before. After the first use of ActiveClass in CSE 12 (third week into the term), he said:

> *The most surprising aspect from today is seeing students ask questions that I don't recall ever being asked in prior versions of CSE 12. A few of these questions were especially insightful. I was very pleased to answer these questions that hadn't occurred to me, and the result is that all students were able to benefit.*

His response also points to the fact that even students who don't use ActiveClass directly are still potential beneficiaries.

Putting these observations together with our detailed session data from ActiveClass, we found that ActiveClass affected the ecology of the classroom setting in several distinct ways. To start, it gave the students the ability to ask questions without revealing their identity, thus resulting in a broader range of questions. This in turn gave the professor the ability to pick questions to answer (not people to ask questions), thus filtering the discourse in the speaking modality. Yet, the professor did not choose these questions in a vacuum; ActiveClass gave the students the ability to vote on questions, providing information to the professor that could influence the filtering of the spoken discourse. It gave the teaching assistants (and the students, too) the ability to answer questions within ActiveClass, often questions that were filtered out of the spoken modality.

It is notable that each "feature" of ActiveClass gave something *different* of value to two or more parties. For example, although students may have been motivated to ask questions in ActiveClass by a certain level of anonymity, the professor in contrast liked this feature for the ability to pick and choose questions (rather than people who ask questions). Thus, we find that ActiveClass improved the fitness of

question-asking by moving the focus from the *people* who asked the questions to the *questions* themselves. This is the fundamental conundrum for both student and professor in the question-asking act: the student raises his or her hand (or not), unsure whether the professor will embrace the question; likewise, the professor calls (or does not call) on the student, unsure whether the student's question will be worth the class's time. With ActiveClass, the question is revealed—and even voted on—without the student being called on, thus saving both the student and the professor possible discomfort. Questions that the professor will not or cannot take can be answered within ActiveClass itself by a TA. In essence, then, the fitness gradient for a question is dramatically reshaped from a very steep curve based on guesses by both student and professor, to a shallow curve based on the question itself.

It is notable that this practice was not born whole, but emerged through "experiments" on behalf of the professors, students, TA's, and researchers. Like Brand's shearing layers, variations on practice could be achieved at differing rates depending on the medium. By exploiting affordances (e.g., answering a question with the asking feature), students could attempt and learn from innovation with a minute's effort, whereas the materialization of practices in ActiveClass's implementation could take a day or more. This is beneficial because practices are probably best not materialized for all to use unless the low-cost innovations show some benefits on their own.

Finally, the last essential element for the fitness of ActiveClass was the professor's tolerance for using PDAs for "unapproved" activities such as instant messaging and playing games. Both of our professors took the view that it was their responsibility to create an environment that attracted the students' attention, and thus tolerated such activities as long as they didn't distract other students in the class. In this case, the small display and pen-based input—cited as problems in the next section—were a benefit, as they induced minimal distraction.

3.3. The Physical Aspect

Students must use their PDAs within the constraints of the physical setting of the class and with myriad other physical artifacts. Our students' desks were designed to accommodate standard-sized notebook paper and no more, and are slightly sloped towards the student. Students' other artifacts typically do not require direct line of sight or a flat surface. For example, students regularly bring water bottles, placed between the students' legs or on the floor, where they can be easily reached by feel.

Like paper, use of a PDA requires line-of-sight access for reading and interacting, and it has a limited viewing angle. The PDA's small screen means that text on the screen is close together. Because most of what is on screen is clickable, some precision is required by users. Students complained that "I have trouble seeing which one I voted on" and "The screen is so small that I click the wrong thing." The precision required by ActiveClass demands that students place their PDAs as close to line of sight as possible. Consequently, PDAs end up competing with paper for desk real estate, leading to a large set of adaptive behaviors.

Some students, finding the management of additional objects inconvenient, chose not to use their PDAs. Some who regularly brought their PDAs did not always use them. Their explanations for this included "I don't use it unless other people do" and "I log in when the professor tells me to." In other words, the benefits they received from using the system were sometimes insufficient in their judgment to justify the coordination costs of incorporating the PDA into their practices.

Students using the PDAs incorporated PDA "postures" into their object-using practices, most to keep their PDAs within easy use-distance while maintaining the primality of paper as a working medium. Some students chose to balance their PDAs on the edges of their desks, supporting it with the fingers of their non-writing hand. Others chose to rest it on one of their legs. Still others implemented a "flying PDA" posture, where they held their PDAs above their heads in one hand while balancing their non-writing-arm's elbow on the desk or against their chest. Finally, a popular, if time consuming, PDA-management style was simply placing the device on top of the paper on top of the desk. When used this way, the PDA occludes much of the page, requiring frequent movement of the PDA.

A crucial disconnect between student practice with ActiveClass and without is in the relationship between ActiveClass and students' notes. For many students, note taking is a critical activity. Notes form a bridge between lecture material and out-of-class practice. Students studying or doing class assignments often make use of their notes while performing these activities. ActiveClass, both because it is physically detached from students' notebook and because it contains content not typically found in notes, was not deeply connected to note-taking practice. Students asked "How can I use this to study?" To answer this question, we added an archival feature to ActiveClass that allows users to view a record of previous sessions in the system, including poll statistics and questions and answers.

Students also needed to be accommodating of the technological faults of this new generation of PDAs, the ActiveClass system, and the campus's wireless network. It is well known that there is a low gradient between temporary, minor glitches and the abandonment of a technology. We found that many devices needed to be rebooted regularly. Other, more difficult to localize, technical frustrations with ActiveClass required regular attention by students. Sometimes, for example, PDAs refused to recognize the wireless network in the classroom.

4. CONCLUSION

Increasing class size and diversity raise pressures against classroom participation, and hence active learning. Mobile computing has the potential to bring new modes of participation into the classroom. To this end, we introduced ActiveClass and explored its potential impact through use in three large introductory CSE classes.

Our initial attempts to understand the effects of ActiveClass on participation led to an ecological perspective on the classroom setting, revealing powerful dynamics that influenced the constitution of classroom practice. Implicit attention to these forces led to an ActiveClass design that was acceptable to all parties, although material forces, some difficult to change, continued to act against the tool's use.

Widening our unit of analysis via an ecological perspective enriched our understanding of participation, shifting from a focus on individual personality types (i.e., shyness) to the nature of the questions themselves. From this perspective, we discovered that ActiveClass contributed to a broader range of discourse in our classroom setting, potentially benefiting everyone.

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This work was supported by a gift from HP, support from the California Institute for Telecommunications and Information Technology (Cal-(IT)^2), NSF Grant IIS-9873156, and the ActiveWeb project, funded by NSF Research infrastructure Grant 9802219. Thanks to David Hutches, Susan Leigh Star, Gabriele Wienhausen, Pat Neill, and Jim Hollan for their help, and Intel for the gift of a network processor.

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