Everyday Encounters with Context-Aware Computing in a Campus Environment

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Abstract. As ubiquitous computing technologies mature, they must move out of laboratory settings and into the everyday world. In the process, they will increasingly be used by heterogeneous groups, made up of individuals with different attitudes and social roles. We have been studying an example of this in a campus setting. Our field work highlights the complex relationships between technology use and institutional arrangements – the roles, relationships, and responsibilities that characterize social settings. In heterogeneous groups, concerns such as location, infrastructure, access, and mobility can take on quite different forms, with very different implications for technology design and use.

1 Introduction

Since its origins, a fundamental motivation for Ubiquitous Computing research has been to extend the computational experience beyond its traditional desktop confines. Advances in the processing power and networking capacity of computational devices, along with progress in power management, size and cost reduction, etc., allow us to envision a world in which the experience of computation can be extended throughout the everyday environment, available where and when it is needed.

Shifting the context of computation from the restrictive but well-understood confines of the desktop to the broader and messier environs of the everyday world brings both problems and opportunities. Amongst the problems are the difficulties of managing power [32], locating people, devices and activities [20, 33], and managing interactions between mobile devices [4, 26]. Amongst the opportunities is the ability to adapt to the environment. Recognizing that different places and settings have different properties and are associated with different activities, researchers have become interested in how computational devices can respond to aspects of the settings within which they are used, customizing the interfaces, services, and capabilities that they offer in response to the different settings of use. Context-aware computing attempts to make the context in which technologies are deployed and used into a configuration parameter for those technologies.

A range of context-aware computing technologies have been developed and explored. Perhaps the most common context-aware systems are those that respond to aspects of their location (and, by inference, the social activities being conducted in those settings), e.g. [2, 15, 31]. Context-aware computing presents a number of challenges on technical, analytic and conceptual grounds; not only are there difficulties in inferring context from noisy information, but the very notion of context as a stable feature of social settings has been challenged and is an active area of research consideration, e.g. [18, 23, 30]. However, in this paper, we want to consider context of a rather different sort – the social, organizational, and institutional contexts into which context-aware and ubiquitous computing technologies are deployed.

This broader form of context has, of course, long been an important concern for interactive system developers of all sorts. Research and development experiences over the past thirty years have repeatedly taught us that the success or failure of technologies depend at least as much on the appropriateness of those technologies for specific settings of use as they do on the features of the technologies themselves. Accordingly, as Grudin has noted [25], the focus of attention in interactive system development has gradually moved outwards, from the technology itself to the setting within which that technology will be employed. However, despite ubiquitous computing's interest in understanding how technologies might respond to 'context', this broader context and its impacts on the adoption and use of ubiquitous computing systems has been largely neglected.

In this paper, we report on an empirical investigation of the use of a ubiquitous computing system blending mobile and location-based technologies to create augmented experiences for university students. In particular, we focus on how the technology fits into broader social contexts of student life and the classroom experience. Our study highlights a number of features of student living – from broad concerns such as the temporal structure of everyday life to mundane concerns such as infrastructure access – that can significantly influence the effectiveness and uptake of novel technologies, and in turn suggests that studies of the social organization of everyday activity can provide a strong foundation for computer system design.

2 Institutional Analysis

Our goal in this paper is not to present an evaluation of specific technologies, but rather to use one particular technological setting to reflect upon some broader patterns of technology use, with implications for future designs. Analytically, we take an institutional approach.

2.1 Institutions

Institutional analysis is a 'meso-level' approach to understanding social settings. It falls between the fine-grained analysis of particular settings, such as ethnomethodology, and the broad accounts of social action captured by more 'classical' sociological approaches, such as Marxist or structuralist analysis.

'Institutions' are recurrent social patterns that structure and provide settings for action; they define roles, responsibilities, and expectations that shape and give meaning to encounters between people [10]. Institutions, then, are not specific social entities, but common social forms. Examples of institutions include the family, organized religion, professional sports, education, the law, and traditional medicine. What is of particular interest is the *enactment* of institutions; that is, the way in which they are produced and reproduced in everyday conduct. Institutions give shape and meaning to social interactions, but are also produced and sustained through those interactions.

Given that many ubiquitous computing technologies are developed, deployed, and evaluated in university settings, our particular institutional concern is with student life on a university campus and how these institutional arrangements manifest themselves for students day-to-day. Institutional arrangements – the role of students in the university, their relationships to each other and to other social groups, the expectations placed upon them – are things that students routinely encounter and navigate. They do so in their formal interaction with the university bureaucracy, such as when registering for classes, graduating, or facing disciplinary proceedings; more importantly, though, they also do so casually in the course of every day, as they deal with each other and even with the physical fabric of the campus.

2.2 Institutional Perspectives on Student Life

We are interested in the institutional character of student life. A number of studies have examined aspects of this.

Eckert's [19] study of high school student life identifies the central significance (to the students) of social polarization, around participation not just in the school's formal program, but in its *agenda*. In her studies, 'jocks' and 'burnouts' are social categories that pervade every aspect of life – from what to wear, who to talk with, and where to have lunch, to participation in class, forms of socializing, and expectations of life after graduation. Competition between these social groups, and the process of moving between peripheral and central positions within them, is a dominating theme in the everyday life of the students.

Becker and colleagues [5] studied specifically academic elements of students' college experiences. In other domains (personal, political, social, etc.) students are able to negotiate with university authorities or claim some autonomy from them, but within the academic arena (classes, course requirements, curricula, etc.) they are subject to the dominance of the university. Like others in positions of subjection, they respond by creating an 'oppositional culture' to protect themselves from the whims and vageries of faculty and administration. Becker and colleagues describe an essentially economic model in which work is 'traded' for a good grade point average (GPA); intellectual interests are, to a large extent, subjugated to an overriding concern with a 'good' GPA (where 'good' is, clearly, a relative term), which in turn affects everything from parental approval and financial support to social standing and dating opportunities. Here, students model their relations with faculty and the university as an exchange system, and the various aspects of college life are refracted through the GPA lens.

In addition to illustrating aspects of the structure of student life, these studies also illustrate what it means to take an institutional perspective; they focus on relationship between students' mundane experiences and the patterns of roles, relationships and responsibilities that make up the domain. These structures provide the interpretive resources that everyday experience is meaningful to people within social settings. Here, we take a similar approach, focusing especially on the place of technology in students' everyday engagement in campus life. In analysing our field data, we are interested in how technology is encountered, used, and applied in institutional settings.

3 Ubiquitous Computing in a Campus Setting

The motivation for our study was to look at ubiquitous computing technologies 'in practice.' Our interests were two-fold. First, we wanted to examine the factors that influence adoption and use of ubiquitous computing technologies, and to analyze the factors that contribute to success and failure. Second, we wanted to study the *emergent practices* of ubiquitous computing – aspects of collective practice that emerge when a technology is put into the hands of an active user community.

There are many reasons to expect that campus environments are ideal for the development, deployment, and testing of ubiquitous computing technologies. Clearly, many technologies are developed in university research, and campus environments are therefore convenient. They are highly networked, with strong infrastructure support services. They are populated by large numbers of potential (and cheap) test subjects, who are adept with computers and eager to explore new technologies and opportunities.

Many ideas for ubiquitous technology have been proposed to facilitate campus environments. Weiser for example, made several suggestions for context-aware and ubiquitous computing technologies for campus environments; some have been deployed in the Active Campus (buddy and TA locator), others are related to the general student life (diet monitor) [36]. Several similar functions have also been implemented in the 'Aware Campus' tour guide at Cornell University [12]. It provides visiting students with a social map, illustrating where other students have visited and how much. The Aware Campus guide also lets users attach virtual text notes to a specific location; the Aware Campus refer to this as 'annotated space', where Active Campus calls it virtual graffiti.

Using computing technologies for university teaching is not only widely applied but also well researched. Research generally focuses on improving the lecturing situation [22] and the class atmosphere [35]. Other research focuses on augmented note taking such as NotePals that gives a group of users, for example as a class, access to each other's notes [16]. NotePals is a PDA based system that supports note and document sharing; in its use it is similar to Active Class which is presented in the next section. An example of a larger project is Classroom 2000 (now called eClass) at Georgia Tech [1]. The goal of Classroom 2000 was two-fold: to facilitate the classroom with a way of capturing the lecture for later access to the students and to provide the students with an efficient method for note-taking [3]. Through evaluation the Classroom 2000 team found that although students claim they changed their note-taking habits, they didn't feel strongly that their performance in the class had improved. The students in our study had similar comments that even though the technology can change habits and study structures, their overall performance has not changed.

Another relevant piece of research investigates the increasing use of laptops in the university classroom in general [13]. The authors draw out the advantages such as instant feedback (not unlike the polls and rating sections of Active Class) and online quizzes. Although they point to negative effects such as cheating on tests by surfing for answers when this is not allowed, the overall problems of inattentive students that we find are not mentioned. Moreover, the authors focus on lectures where all students have laptops, meaning classes where this is obligatory. Although requiring all students to have laptops would surely increase the use level of Active Class, it is not likely that such an initiative would happen at public universities any time soon. We have in our study looked at more realistic factors, considering the present state of technology to find what premises exist for context-aware technology in a campus environment.

3.1 Research Setting

Our empirical data focused on the elements of the Active Campus system, developed and deployed at UC San Diego [9, 24]. Active Campus is a pioneering effort in wide-scale ubiquitous computing design. To date, most 'ubiquitous' computing experiments have been far from ubiquitous, generally restricted to specific laboratories and buildings or to specific research groups. Consequently, it has been hard to develop an understanding of what it means for ubiquitous computing to be used ubiquitously – over a wide area, with an expectation that it is available to others, and so on. In contrast, then, Active Campus is designed to explore the broader challenges and effects of introducing ubiquitous computing technologies on a larger scale, both in terms of infrastructure and use. It aims to support students, teachers, researchers and visitors across the UC San Diego campus, and it has attempted to introduce these technologies on a fairly broad scale, encompassing hundreds of users.

Active Campus is an umbrella project which draws together many technologies, functions, applications and services. The core Active Campus infrastructure provides a range of location-based services available through mobile and handheld 802.11b clients, on a densely available network across the campus.

Access point triangulation allows 802.11b-based devices to identify their own locations, and some facilities support integration with other mobile devices such as advanced mobile phones. Services including navigation mechanisms, providing maps showing users' presence as well as landmarks, and graffiti that the users can 'tag'. Further, Active Campus provides a collective instant messaging client, so users can message each other through the system, and a 'conversation locater', where open conversations are placed at certain locations. This way, other people can see where the conversation actually took place for both/all people in the discussion.

Active Class is part of Active Campus [28]. Unlike the core Active Campus functionality, which is designed for general use, Active Class is designed specifically to support classroom teaching. Specifically, it uses mobile devices to provide a further channel of communication between teacher and students in lecture settings. It is built around three primary functions – questions, polls, and ratings. The question section makes it possible for students to ask questions anonymously over the internet and to vote on which questions they think are important to answer. Anyone can answer the questions as well and do this anonymously, but most of the time, it is meant to be raised in class and answered by the teacher. The poll section enables the administrator (usually a teaching assistant) to post a question, for example in regards to which new material should be given extra attention, and the students can then indicate their preference real time; polls allow students to vote on responses. Finally, the rating section lets students rate the speed of the lecture as 'too slow', 'just about right' and 'too fast'. The students can also rate the quality of the lecture on a scale from one to six. The intent of Active Class, then, is to provide further channels of communication between teacher and students, and to broaden participation in class by lowering barriers to interaction.

3.2 Method

Since our research goals were to look at influences of adoption and analyze the emergent practices from an institutional view point, we found primarily qualitative research methods to be appropriate. Rather than simply counting instances of activities, our goal was to understand the technological setting from the perspective of the participants.

Our study took place over a period of 4 weeks, from a point almost half-way into the academic quarter until the last class. We tracked two sets of users. The first consisted of upper-division undergraduate students enrolled in a large (141 students) computer science class on the subject of advanced compiler theory. The second set consisted of freshman students enrolled in a small (4 students), discussion-oriented 4-week seminar class in new media arts (in fact, the topic of the class was the impact of ubiquitous computing classes on future campus life).

We gathered data in three different ways: first, through in-class and out-of-class observations; second, through questionnaires administered to class members; and third, through more focussed interviews with a smaller number of students.

The questionnaire for the freshman seminar aimed at retrieving basic knowledge of the student's experience with ubiquitous technologies and the questionnaire for the larger class focused on their use of Active Class and general class behavior. Observations were made throughout the 4-week period in all the seminar classes and all of the bi-weekly computer science classes. Observational notes were made constantly in regards to the students overall behavior and the activities on the Active Campus technology real-time. The observation was conducted as participant observation but although the observer blended fairly well into the large class, the teacher made the class aware that they were being 'observed' and thereby created an awareness about the observation. The advantage of this was that the students who were interviewed afterwards had thought more about their use of Active Campus and it was not the observer's impression that the awareness of observation had changed their behavior. The seminar, on the other hand, was such a small class that the observer became very noticeable. At first this seemed to create shyness among the students, but after the first half hour, the excitement of the technology and the focus of the class took over their attention.

Interviews were conducted one-on-one in order to gain closer insight into the factors of use in relation to both parts of the system. The interviews with the seminar students were both one-on-one and in groups during class time. Since the seminar was much less structured and often took place outside on campus, the interviews naturally became less structured and sometimes mixed with the observation. All interviews were semi-structured, focusing on common issues but encouraging the respondents to discuss other things that they might find relevant for the system or just general campus behavior.

3.3 Participants

The participant selection was limited by the general use of Active Campus and Active Class. At the time of this study, only one class (as well as the seminar) used Active Class and a limited number of students used Active Campus itself. 35 students participated by answering questionnaires, where four of them were the participants of the freshman seminar and 31 were students in the advanced compiler systems class where Active Class was used. The four freshman seminar students were interviewed as well as 8 of the computer science class students. The Freshman seminar consisted of three females and one male, three of them being 18 and one girl being 19 years old. The eight computer science students were all seniors, between 22 and 26. Six were male and two were female. Table 1 shows general demographics of the participants from the Active Class questionnaire and observational study.

4 Campus Experiences of Ubiquitous Computing

One reason that students (especially computer science students) are often selected as a target population for trials of novel technologies is that young people are often early adopters of digital technologies. Certainly, we found that our

Table 1. Participants of the Active Campus study.

	Active Class Data		**Seminar Data**	**Collective Data**
	Questionnaire	**Observation**	**Observation & questionnaire**	**Interviews**
N	31	98–130	4	12
Average age	22.5	N/A	18.25	21.8
Females	23 percent	7–14 percent	75 percent	42 percent
Level of study	4th–6th year undergrad	N/A	Freshman	Freshman–6th year undergrad

participants fit this general profile. Only two of our 35 participants did not have a mobile phone and the average ownership was 3.7 years. Over half (55%) had an MP3 player. Many (42%) had a PDA but only two students were seen to use them in class. Several had also owned pagers before but only one person still used his.

However, familiarity with, and adoption of, novel technologies does not necessarily lead to their use across settings. So, for example, while 65% of the respondents to the questionnaire reported owning a laptop, only 31% of these reported always bringing their laptop to class. Further, observation showed that only a few actually *used* those laptops in class; in interviews, many reported that their laptops would remain in their bags, despite the facilities available for them. During the course of the study, 13-17% of the students had laptops up and running on their desk during class. So, although technology penetration is often cited as supporting the adoption of new applications and services, it is clearly a necessary but not sufficient condition.

4.1 Mobility

Mobile access to information and services is a central element of the ubiquitous computing model. Ubiquitous computing technologies are, almost by their nature, mobile ones – they move around with us in the world, and provide us with access to information and resources as we move from place to place. Accordingly, a good deal of attention has been focused on user communities on the move – tourists [11, 15], conference attendees [17], and others. Focusing on those with a high need for mobility has allowed us to explore the sorts of location-based services that might be useful. Students are, on the face of it, another group whose activities are inherently mobile, as they move around a campus setting from class to class. Active Campus incorporates a range of location-based facilities, such as geo-messaging, navigation, and 'buddy finders' as a way to help mobile students.

Looking at how location and mobility manifest itself among undergraduate students (who are the primary target population for Active Campus), we find a different set of factors influencing their behavior. These students are indeed highly mobile, moving around the campus between classes, laboratories and social spaces. However, we would characterize the students' experience not so much as *mobile* but more as *nomadic*.

The critical distinction is the presence of a so-called 'base'. Many of the research studies of mobile work conducted to date focus on *roving* in office work. In this form of mobility, people may move around through a space, but they also have a 'base' of some sort – a desk, in the case of the designers studied by Bellotti and Bly [7], a control room in the case of the waste-water treatment plant described by Bertelsen and Bødker [8], and so on. In the university setting, this is also the experience of faculty, researchers, and graduate students, but it is not the experience of undergraduate students, most of whom have no assigned space. What the students experience is not simply mobility, but nomadism – a continual movement from place to place, none of which is inhabited more than temporarily, none of which can be relied upon, and with no notion of individual ownership. These issues of 'base' and ownership set the case of undergraduate students apart from the simpler case of roving workers.

The students we interviewed talk about how their classes are spread out through the day. For them it means that they have a lot of in-between time where they either study, meet up with friends, eat or even sleep. Not a lot of space is reserved for these breaks and the 'Library Lounge', according to our participants is almost always full of students reading or typing on the few available desk-top computers. One student is lucky enough to have a desk in a shared office because he works on campus as well and describes a typical day:

> These days I am just so busy with school. Basically I wake up to come to a class or I come to work. I work at [local research center] ... After that I'll generally have a break, my classes are somewhat spaced out. During the break period I either eat food or do school work... I tend to like walking around, sometimes I do [school work] in my office, sometimes I do it various places around the Price Center. A lot of of the time I go to the Library Lounge ... There are always a lot of people sitting around there, working or just hanging out.

This nomadic existence leads to a number of mundane practical concerns which are, nonetheless, extremely significant for technology adoption. One of these concerns the material that must be carried around, and its weight. Those of us with offices and desks may be mobile, but need only take with us what we need for the next meeting, class, or appointment; for the students we studied, though, the daily environment provided few places to leave belongings (and fewer yet that could be reliably returned to between activities). This places a significant barrier to discretionary use of computer equipment. One of the students even reported that he found his PDA too heavy to carry around!

Another significant consideration is access to traditional infrastructure services, and most particularly power. While sources of power are certainly available to students, they tend not to be *reliably* available, and reliability is critically important when one is budgeting a scarce resource. If the students are not sure when they are able to charge their laptop next time, they are likely to be reluctant to use it for anything other than essential tasks. Another influential factor is one of social kind. Five of the eight computer science students we interviewed reported that they preferred to go to the computer science lab to their programming projects and other computer required tasks. They all reported that this was mainly for social reasons, here they could also talk to other students and even sometimes get help with their work. Two of these students felt that lab work contributed significantly to their social life and the community of their class. They preferred this to working by themselves on a laptop. The behavior indicates that the level of mobility fosters a need for some kind of social but work oriented meeting place but since the lab is common and doesn't allow personal space, it does not offer a work base.

4.2 Location

Separately from the problems of mobility, we can also ask, how and when does location manifest itself as a practical problem for students? Location-based services developed in other settings point to a range of ways in which ubiquitous computing technologies can help people resolve location-based problems - the most common being finding resources, navigating in unfamiliar environments, and locating people.

As we have noted, students' experience is primarily nomadic, and since their activities and concerns are driven as much by the demands of social interaction as by their studies, we had anticipated that services such as the people finder would be of value, helping them to locate each other as they moved around a campus environment. However, further examination showed that, in fact, location rarely manifests itself for them, practically. The students' nomadic existence is, nonetheless, strongly structured; the students we studied live highly ordered lives, at least within the confines of a particular academic quarter. Their location at any time in the week is dependent on their schedule of classes, and the locations where those classes are held. One student describes her lunch habits:

> Well, it is set up, like before we go to class. My room mate and I have lunch every Monday, Wednesday, Friday, because we have class that get out at the same time. Tuesdays, Thursday I meet my guy-friends at [a fast food restaurant on campus]. It is a set thing.

Because of the regularity of their schedules, the students, then, tend to find themselves in the same part of the campus at specific times in the week. Similarly, their friends live equally ordered lives, with locations determined by class schedules, and our respondents seemed as familiar with aspects of their friend's schedules as with their own. Mutually-understood schedules, then, provide them with the basis for coordination. For example, students tend to have lunch with the same people, and in the same places, on a weekly basis, those places and people determined primarily by their collective schedules.

Our observations then suggest that, for undergraduate students, location manifests itself as a quite different problem than it does for faculty, researchers, and graduate students. While the experience of the regular employees of a university is of people who are hard to find due to schedule variability, and who might be sought in a 'home location' but found somewhere else, these problems appear quite differently to undergraduates. There being no home base, students have no expectation of being able to find each other in fixed places; instead, class schedules become a primary orienting mechanism around which location is determined and coordination is achieved.

4.3 Using Technology in the Classroom

As we suggested earlier, the Active Class component of Active Campus provides specific support for the classroom experience. In addition to the practical matters concerning the use of technology in campus settings in general, the classroom introduces a number of important considerations all of its own, in terms of both design and activities.

The primary focus for support is the communication channel between students and teachers. Active Class provides a range of mechanisms to increase this communication, through questions, polls, and ratings. One specific feature of the Active Class design is that questions are anonymous. By making questions anonymous, the designers of Active Class hoped to overcome possible pressure on students, encourage question-asking, and narrow the gap between those who participate in class and those who do not. When asking the students if they ever felt that shy about asking questions, three of the eight students interviewed reported that they did not feel comfortable at all asking questions in class. They also reported that they only answered the teacher's question if they knew it was '150% correct'.

We observed the use of Active Class during eight lectures over the course of our study. Participation using the system was lower than might be hoped, due to some of the problems listed earlier; the practical difficulties of making use of laptops and PDA devices, especially in a class held towards the end of the day meant that only a small proportion of the class would make use of the Active Class facilities.

Although students were asked to log into Active Class by the professor in the beginning of each lecture, only few actually did so. Although between 13 and 20 laptops (and 0–2 PDAs) were in use in every lecture, only between two and eight users were logged in to Active Class. Similarly, rather than being related to the number of laptops in use, the number of logins to Active Class generally decreased through the quarter. When asking the students through the questionnaires why they did not log in, they responded that they had no questions and therefore could not see the use of logging in. In fact, according to the questionnaire results, the laptops in class were rarely used for anything other than casual surfing or communication (email or instant messaging). Only a few (7%) of the students who brought their laptops to class used them for note taking.

Interviews suggested that one major factor of not using the laptop in class was its limited options for unstructured note taking. Notes often consist of loose drawings of stacks and queues and memory allocation analogies, and a text editor does not allow these types of notes. Because the auditorium's chairs are limited to flip-up tables with room for just one Letter-sized (A4) notebook, the students had to choose between a paper notebook or a laptop. One student said that when he could afford a tablet PC, he would start using it more in class, because it facilitates pen-based input. Previous user studies of Active Campus arrive at similar findings that the PDA or laptop competes with paper in the sense of 'desk real estate' [24].

Ironically, this small degree of participation through Active Class can end up exacerbating the effects that it was designed to relieve. Since only a small number of people were using the system, their participation was more visible. Like verbal question-asking, it was restricted to a subset of class participants. In our observations, use of the system was actually higher amongst those who were also attending to the class and participating more fully (sitting towards the front, asking verbal questions, etc.) Although designed to broaden participation by incorporating more people more fully into the class activities, Active Campus in this restricted setting seemed instead to heighten the participation of those who were already engaged with the material, providing them with more channels through which they could engage, and new avenues for exploring material and participating in class. Ironically, then, this may broaden rather than narrow the gulf between those who participate more and those who participate less. This is, perhaps, a consequence of some of the other features noted; Active Class might serve its original function if the technology were used more universally, so that using the system were less distinctive and notable.

By exploring how much attention people paid to the lecture we aimed to see if laptops was a disturbing factor and what the level of attention seen from the students point of view actually was. One claimed to pay close attention to the lecture in the questionnaire returns and two admitted that they were not paying attention at all. The latter two were not using laptops during the lecture, which indicated that non-attention is not necessarily due to laptop use! The rest of the students placed themselves in the two middle categories when rating their own level of attention ('followed most of the lecture' or 'tried to follow the lecture but drifted off occasionally'). The attention level was also affected by the students' understanding of the subject. One student admitted in the interview that there was a lot of the material she simply did not understand. When asked if she thinks the lecturer goes too fast and that perhaps Active Class could help her she responded:

> Uhm.... a little bit but for the most case I like, when I am in there I kind of don't understand a lot of the stuff that he is talking about... I just kind of wait 'till the end when he... pauses afterwards when I can look over it and just like talk about it with my friends...

We found a slight correlation between where the student sat in the particular class and how many different tasks the student did on his/her computer. The

Table 2. Observational results from the use of Active Class.

	Number of Students in class	Number of laptops observed up and running	Number of students logged in to Active Class	Number of questions asked through Active Class
Lecture 1	132	16	8	, 4
Lecture 2	97	14	5	1
Lecture 3	130	17	6	0
Lecture 4	98	13	3	0
Lecture 5	105	18	3	1
Lecture 6	140	20	4	0
Lecture 7	98	17	2	2
Lecture 8	138	18	2	0

further up towards the back the student had placed him/herself, the more tasks the student did on the laptop.

Of course, it's important to note that Active Class is not the only technology in use in the classroom; it must coexist with existing technologies for lecture presentation, such as Powerpoint, whiteboards, etc. Powerpoint naturally lends a relatively linear structure to the presentation. Once in a while the professor draws on the slides to emphasize a point (or to correct typing mistakes), through his tablet PC. This increases the interaction that the teacher can provide and enables him to illustrate points raised in class that otherwise would need black board space and thereby a shift in medium. However, the classic path of the lecture reinforces the fairly static one-way interaction. Since the introduction of technology for the sake of technology is not desired in a class room, the limitations in technology use are also partly due to the lecturing tradition as it is present at universities today.

5 Discussion

Although we have focused on Active Class and Active Campus in this description, it is not our intention to critique these systems in particular. They provide concrete examples of a set of general phenomena which are of great importance when attempting to design effective ubiquitous computing experiences at a large-scale, as the ubicomp research community must do to be successful. We focus on five concerns here.

The first is that technological designs must be sensitive to the *variability of institutional arrangements*. This does not simply mean that different user groups have different needs; rather, it means that technology use is systematically related to people's roles and relationships towards each other and towards other infrastructures and technologies. The particular relevance of this concern is that design practice frequently crosses institutional boundaries, and it is critical that we are attentive to these boundaries and their implications. So, as we have seen in the case of Active Campus and its provision of location-based services, "location" manifests itself in daily life quite differently for undergraduate students than it does for faculty, staff, graduate students, and researchers in a university setting. Undergraduate students, because of their role in the university and its life, find themselves subject to a quite different set of demands; the notion of location as a problem in the way in which researchers encounter it requires certain institutional opportunities – for discretionary movement, control over one's own time, flexible scheduling, etc. – that simply does not arise for students. This same problem of institutional discontinuities has also affected other ubiquitous computing efforts, most especially those concerning domestic technologies (which are subject to quite different institutional norms than obtain in office settings). As ubiquitous computing technologies move out of the laboratory, the issue of heterogeneous encounters with technology will become increasingly important. Cross-cultural studies of technology use, such as Bell's studies of the home [6] or Ito and Okabe's investigations of mobile telephony [27], are instructive in this regard.

Second, as others such as Edwards and Grinter [21] or Rodden and Benford [29] have noted, *quite different temporal dynamics apply to laboratory settings and real-world settings*. In laboratory settings, novel technologies and spaces are designed around each other; to set up a new experimental system, we can clear other things out of the way, set a new stage, and coordinate the arrival of different technologies. In real-world settings, though, new technologies must live alongside old ones, new work practices must live alongside old ones, and new forms of working space must coexist with those that are already there. An augmented classroom will also be used for traditional teaching; and similarly, new teaching practices may be introduced into settings that are designed for (and must still support) traditional teaching. Technology is *always*, *inherently* available differentially in real-world environments. Again, this is a consequence of the institutional perspective; it is a consequence of the ways in which ways of working become 'sedimented' in technological and physical settings.

Third, and relatedly, we must be *particularly attentive to infrastructures of all sorts*. As Star and Ruhleder [34] have noted, one property of infrastructures is that they are embedded in settings, and hence often become invisible. This applies not just to technological but also to procedural infrastructures (ways of achieving ends, such as administrative mechanisms and resources) and conceptual infrastructures (ways of making the world organizationally accountable, such as category systems and schematic models.) What is infrastructure to one person – invisible, unnoticed, and unquestioned – is an obstacle or source of major trouble to another. Infrastructures make their presence (or absence) felt largely through the difficulties that render them suddenly noticeable. In the case of the technologies we have discussed here, for example, the availability of power and the design of classroom seating, which are normally unnoticed elements of everyday campus life, become suddenly visible, apparent, and problematic. In retrospect, these may seem obvious, but it is this very taken-for-granted nature of everyday infrastructures that renders them so difficult to account for successfully in design. More importantly, this perspective on infrastructure places an emphasis not simply on the presence of certain kinds of technologies (power, networking, etc.) but on other elements that condition their practical 'availability', including control, ownership, legitimacy, training, etc. These are as much an aspect of 'ubiquity' as the presence of a technology.

Fourth, the institutional perspective we have been developing here suggests an alternative way to assess technology adoption. Our approach has been to look not simply at particular individuals and their use of the system, but rather at *the relationship between technology and local cultural practices.* While traditional usability analysis concerns specific individuals, the impacts of technology come not just from individual but from collective usage patterns. A collective perspective on the setting that we have been examining suggests new ways to think about the impact of technologies. In particular, rather than asking how specific students might use Active Class, we might ask rather how a *class* might adopt and use it. Clearly, the question mechanism in Active Class impacts the class as a whole, since the whole class hears the answers. Particular technical strategies have broader impact. For example, providing a public view of Active Class activity might extend the reach of the system to class members without networked devices; the impact of the system could be felt by the class as a whole.

Finally, our investigations draw particular attention to the fact that technologies of all sorts (digital, electrical, physical, etc.) are *a means by which relationships between social groups are enacted.* Social grouping are often stubbornly persistent, at east in the short term. Castells, for example, has noted that, while people's 'social reach' is amplified by access to the Internet, most people use the Internet to seek out others like them, rendering their immediate social contact group *less*, rather than more, diverse [14]. Similarly, while the instrumental role of information technology may be to promote interaction across social boundaries, it may also symbolically reinforce those boundaries. In the presence of other obstacles to common use, the adoption of a technology takes on a symbolic importance; it demonstrates affiliation in the face of adversity and, in a classroom setting, can reinforce the 'grade economy' described by Becker et al. [5] and the social polarization described by Eckert [19].

6 Conclusions

We set out to find how different structures influence the use and adoption of ubiquitous computing technology as well as to trace emergent practices for students in a campus setting. Where students, on the surface, seem like the perfect probes for new technology, their inherent social structures and high level of nomadicity creates a tension between their desired use and actual possibility for use. From the perspective of research, many settled practices and infrastructures within the campus environment are inhibiting not only the adoption of new technology but also the foundation for testing new technologies. Only by looking beyond the technologies themselves, towards the broader institutional arrangements within which they are embedded, can we begin to understand the premises for deployment of ubiquitous technology. General evaluation of new applications is important for purposes of usability but to generate further knowledge of the deeper use structures, for the purpose of future design, analyses of real implemented technologies are fundamental. These considerations underscore the importance of observational methods, studies of real-world practice, and in situ evaluation; and more broadly, they point towards the importance of analyses that look beyond surface features to the practices through which these empirical features are shaped, shared, and sustained.

Many of our observations involve not simply institutional arrangements, but rather how people playing different roles have quite different experiences of those institutions and settings. The developers of Active Campus may have encountered some of these problems earlier than most because their approach pioneers a broad-based use of ubiquitous computing technologies, one that encompasses many different groups. In many ways, it is only the broad scope of the Active Campus development that allows these observations to be made, and it is clear that, as we continue to move ubiquitous computing technologies out of the laboratory and into the everyday world, the concerns that we have explored here (and others like them) are likely to be encountered more regularly. Our observations here demonstrate how observational and qualitative methods can offer a set of sensitizing concepts to help attune designers to the everyday concerns that arise in the use of advanced technologies. In particular, they illustrate the importance of institutional arrangements in the development, adoption, appropriation, and use of ubiquitous computing technologies.

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