A Case Study of an Interdisciplinary Design Course for Pervasive Computing

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ABSTRACT

This paper provides a case study of an interdisciplinary design project course for pervasive computing products. As a team of faculty from computer engineering, industrial design, and marketing, we have run several interdisciplinary design projects with teams of undergraduates from those disciplines. Our paper will detail our process for each of these projects and how that process has evolved with each offering of the course.

Author Keywords Pervasive computing, interdisciplinary design teams.

ACM Classification Keywords Systems analysis and design, training, curriculum.

General Terms Design

INTRODUCTION

This paper provides a case study of an interdisciplinary design project course for pervasive computing. In pervasive computing, computing and sensing elements are seamlessly integrated with everyday objects. Successful pervasive computing products require a balance of engineering, design, and business throughout their development phases. As a team of faculty from computer engineering, industrial design, and marketing, we have run several interdisciplinary design projects with teams of undergraduates from those disciplines. Our goal has been to approximate a start-up product design firm to the extent that is possible in an academic setting, and to provide students with an interdisciplinary experience that will allow them work successfully with other disciplines in industry.

We have evolved an approach to building teams over a series of design experiences for pervasive computing products: pet care products for the elderly, safety on construction sites, dorm rooms for students with disabilities, and firefighter equipment. Our paper will detail our process for each of these projects and how that process has evolved with each offering of the course. The paper will then describe several important elements of our process to leading the course.

The paper will also discuss the several significant aspects of the university that impact the course. Just as we must bridge cultural gaps within the classroom, we must bridge them with our university administration, in terms of course scheduling, credit for the students, and differences in expectations for faculty in different colleges and departments.

INTERDISCIPLINARY DESIGN TEAMS

From a pedagogical standpoint, the students on the teams will have an interdisciplinary design experience that is not currently available in the courses offered by their home departments: The engineering students, who are generally used to solving a well-specified problem, will be exposed to the issues involved in defining a problem and developing an initial conceptual solution. Similarly, the industrial design and marketing students, who are generally used to defining a problem and designing conceptual solutions, will be exposed to the role of engineering analysis in implementing a prototype of a new product. In working with students from the various disciplines, we have found that “when you’re a hammer, everything looks like a nail”: Engineering tends to see a mathematical optimization problem, industrial design tends to see a “form” problem, and marketing tends to see a communication problem. By bringing these groups together and breaking the borders that exist between them we allow for more creative thinking and solutions that are not tied to existing disciplines and pre-conceived solutions. We want the students to become comfortable working in the margins between disciplines, where the real solutions to real problems often reside.

A major aspect of the course is that we do not start with an existing product specification. Rather, we provide the students with an area where we believe there is an opportunity to develop a pervasive computing product, for example, pet care for the elderly or safety on construction sites. We then have them research the types of activities that that area entails—feeding a pet, falling from heights—and from there come up with a set of potential products. From that set, we have them choose the products that they would most like to develop. The remainder of the course is spent designing the product, determining its technical feasibility, and developing a marketing plan.

Given that the design experience is run over a 15-week semester, we must quickly make the students feel like part of a team. We balance the number of students from each discipline so that no one feels outnumbered, and provide a neutral, dedicated space for the group to work. Early in the project, we build bridges over the cultural gaps between disciplines, for example, differences in vocabulary, grading expectations, and dealing with uncertainty. A key element of the process is having a set of like-minded faculty from each discipline who act as role models in leading the course. We set a tone of informality that helps to break down hierarchies between disciplines and demonstrates our own value for interdisciplinarity. We empower the students to take responsibility for the course deliverables and allow teams to be self-organized and dynamically changed as the project progresses from research to product concepts to prototyping.

OVERVIEW OF DESIGN PROJECTS

Our interdisciplinary faculty team has designed and taught four offerings of an interdisciplinary design course in which students designed products that utilize pervasive computing technology [5]. Our interest in the first two projects (pet care and construction site safety) was the products, but we came to realize that the pedagogical aspects of the design teams were as important as, or more important than the products. At that point, we brought an engineering education faculty member (McNair) into the team to add course exercises in team building and to formally study the behavior and processes of the teams [7, 8].

This section summarizes the technical aspects of the projects we have run, and then the following section will elaborate on the evolving set of design goals and processes that we have used in the projects.

Pet care *Aw*areness *S*ystem (PAwS)

Coupey, Dorsa, Kemnitzer, and Martin supervised a ten-week interdisciplinary student design project competition sponsored by Procter & Gamble (P&G) in 2006. Twelve students from five departments (4 from ID, 3 from ECE, 2 from Marketing, 2 from Industrial & Systems Engineering and 1 from Graphic Design) participated in a project to develop a family of customizable, interactive products and services for aging consumers. The Virginia Tech team was one of four universities selected by P&G, based on their review of proposals submitted by more than fifty universities, nationwide. An important aspect of the collaboration was developing a process that effectively leveraged and integrated the disciplinary contributions to build a bridge between identified consumer needs and available technologies. The P&G contest provided constraints that the products were intended to be marketed to the elderly and had to fit with an existing P&G product line. Given those constraints, we developed an innovative extension to one of P&G's already established pet care brands – IAMS: Companions… for life. The underlying idea was that research has shown that the elderly benefit from having pets living with them, but this is just at the time in their lives when they are becoming less able to care for pets. The students identified a range of pet-care activities that were difficult for the elderly and could be improved by the adding some combination of sensors, computation, and networking. Products included an intelligent feeding station, a bathing station, an in-home pet tracking/zone system (top of Figure 1), a smart play toy, and a central system to tie all of these together, the Smart Companion, which is shown in the bottom of Figure 1: The Smart Companion is the data center of the Companions line, serving as a liaison between pet, elderly owner, the caretaker of the elderly person, and the veterinarian.

Pervasive computing for improving safety on construction sites

For the second project, Dorsa, Kemnitzer, and Martin ran a semester-long interdisciplinary design course with 21 students from Industrial Design (10 students) and Computer Engineering(11 students) in the spring of 2007. The projects emphasized the use of pervasive computing to improve safety on construction sites. Job site accidents cost the U.S. construction industry over 1,200 lives and $1 billion each year. Improving construction safety is a primary objective of the industry, insurers, and governmental agencies. Although many construction accidents are preventable through better awareness and communication, the environment is noisy, visually restricting and confusing. A construction environment enriched with pervasive computing embedded in equipment, tools, structure—and even workers' clothing—can revolutionize construction site safety. Pervasive computing can provide real-time feedback to workers and supervisors to prevent acute risks (e.g., falls), and to measure and store data about long-term exposure to harmful conditions (e.g., particulate inhalation). In the envisioned environment, sensors and computing elements embedded in workers' clothing and tools, and in the surrounding infrastructure, are seamlessly integrated, both cognitively and physically, communicating together to create an intelligent environment that assesses the users' needs and assists with their activities. For example, stand-alone devices that track locations of workers, materials, and machines can link to workers through intelligent clothing, and safety and communications devices. The students' research found some major differences between the worker needs on building construction sites and roadway construction sites, so the course products were split along those two lines. For roadway construction sites, the students developed a work zone alert system of smart barrels and an intelligent wearable vest. For the building construction sites, products included crane operater/rigger communication system (shown in Figure 2), noise-cancelling ear-protection that could be attached to a standard hard hat (shown in Figure 3), and an intelligent fall-arrest harness. As with the the PAwS project, there was also a central system that tied the other products together: a set of intelligent boots that tracked the worker's location and collected safety and exposure data each day, which was then communicated to a site-wide system.

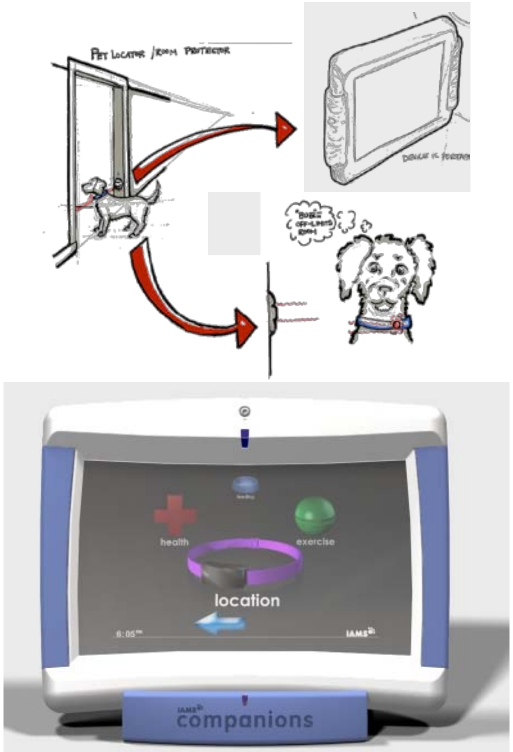

Figure 1. The Smart Companion (bottom) allows the pet owner to view information about the health, feeding, exercise, and location of the pet (top), and can share relevant information with vets and family.

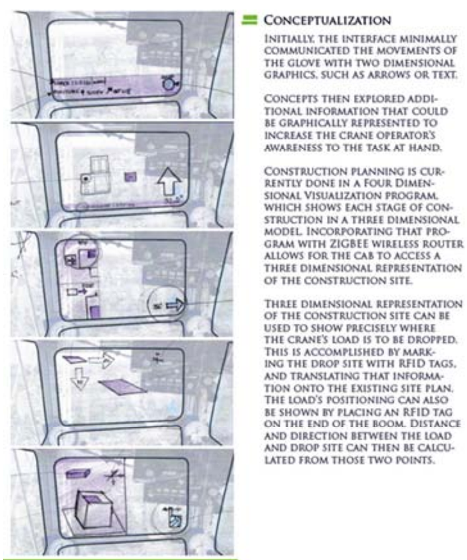

Figure 2. Crane operator/crane rigger communication system, linked in with the construction site's 4D planning system.

Figure 3. Digital rendering of hard-hat mounted active noise reduction concept.

Figure 4. Concepts from the smart dorm course. Left: CARA, an assistive companion robot. Right: A modular furniture system that can be configured before the student arrives on campus via a survey system/virtual room builder application.

Smart dorm rooms for college students with disabilities

Coupey, Dorsa, and Martin ran a semester-long interdisciplinary design course with 21 students, seven students from Computer Engineering, Industrial Design, and Marketing in the fall of 2008. The projects included potential uses of pervasive computing to help college students with disabilities manage aspects of daily living and social networking. This project course involved designing smart devices for dormitory rooms to create a *prosthetic living space*. There has already been considerable effort spent on assistive technologies in the classroom, so we instead concentrated on the theme of "aids for daily living," given that these students have likely grown up under the close care and supervision of their parents and thus require help with independent living. One area of interest was the study of compensating technologies to assist with furniture design, notification systems, and daily activities. Other interests were proactive applications and services enabled by monitoring of behavior patterns using wearable devices and sensors embedded in the room. The projects in this course included an assistive robot (Figure 4, left), a reconfigurable furniture system with an on-line system to help the students choose the furniture before moving to campus (Figure 4, right), a smart mirror for context-aware notifications, an emergency contact tag integrated into a cell phone, and physical embodiment of a student's social network.

Safety gear for firefighters

In the fall of 2009, Coupey, Dorsa, Kemnitzer, and Martin ran a course with 12 students, four each from Computer Engineering, Industrial Design, and Marketing. We took a slightly different approach with this offering than we had with the previous three. Instead of giving the students only a broad product area, we chose to specific that they had re-design the traditional firefighter's helmet to include sensing and communication. But the student research showed there were additional design opportunities in other firefighter gear, including breathing apparatus and protective clothing. There was a general level of unhappiness with the project for both the faculty and the students with this semester. Some of this stems at least indirectly from the narrowness of the initial scope, so we will return to using a broad product area in future classes. In the discussion section below, we will go into more detail about possible factors in the unhappiness with this project.

OVERARCHING GOALS FOR PRODUCTS

As stated previously, pervasive computing means that computing and sensing devices are integrated seamlessly into everyday environments, including clothing, furniture, and living spaces. The advantages and requirements are summarized in the following set of design goals for pervasive computing devices; these goals are fundamental to all of the projects that we have run:

Context-aware: dictates that a device should sense where the user is, who the user is with, and what activity the user is doing, so that the device can proactively tailor itself to the user's needs and intents.

Adaptable: dictates that the system should be easy to tailor to individuals and to particular situations for an individual.

Durable: dictates that the system must tolerate faults, both permanent and transient, that are inherent in the manufacture and use of the device. There is also an expectation that individual components are not repairable and that system functionality should gracefully decline as components fail.

Seamless: dictates that the form factor should be unobtrusive and comfortable – devices will not be adopted if they cannot conform to aesthetic and use norms of the environment.

Easy-to-use: dictates that any interfaces should have no/low cognitive load, that devices should be self-diagnosing/self-reporting for maintenance, and have "Plug and Play" functionality, i.e., self-detecting, and self-assembling as components are activated or introduced.

Scalable: dictates that the device should be able to function in large quantities without interference with each other. Individual products are a part of a family of products that can either stand alone, or work together to provide functionality that is greater than the sum of the individual products.

PROCESS

Our team of faculty brings technical expertise in industrial design, human factors, electrical and computer engineering, business and marketing. We believe that successful wearable/pervasive computing products depend upon a proper balance of technology, ergonomics, and business. The projects described in the previous section have allowed us to develop and refine an interdisciplinary design process that builds upon and bridges our individual strengths to holistically solve the range of issues faced by a pervasive computing product.

The projects were run as a design studio with an open environment where students learned from each other in a dynamically developing systems structure. We provided a space where small group studies are made available to the whole group and groups self-assemble, develop ideas, articulate systems needs and characteristics, and then disassemble and re-assemble based on shared interests and interdependency of their designed components.

Our expectations for students and faculty participating in the projects are based on four principles:

1. Be a "T" shaped person…tall in discipline expertise, wide in general interest and knowledge: A person with depth of knowledge in their discipline (the vertical line of the "T") as well as sufficient breadth of knowledge to bridge to people in other disciplines (the horizontal line of the "T") [6, 9].
2. Check your discipline at the door, contribute whatever you have, whatever you think, whatever you can learn, to the team: Everyone in the class is expected to make contributions at every stage of the process, regardless of their technical specialty.
3. Your team role and participation will change during the problem seeking, brainstorming, alternative development, and schematic prototyping phases of the class.
4. Be innovative…but not flamboyant. A solution should be novel without drawing attention to itself simply for the sake of its novelty. This principle is our pithy statement of the design goals being seamless and conforming to aesthetic expectations for the user's situation. One of our student teams came up with this phrase in the spring of 2007, and it became one of the course's mottos, as illustrated by Figure 5, a picture taken at the final presentations in the spring of 2007.

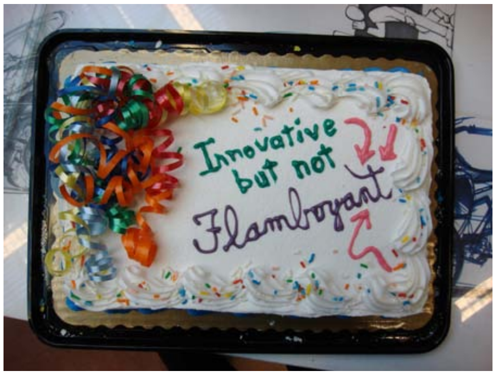

Figure 5. "Innovative but not Flamboyant." The course motto is the icing on the cake at the final class presentation in the spring of 2007.

While each offering of the course has followed a slightly different path, the general outline of the course is as follows:

Martin and Dorsa relate the nature of becoming an expert to the ability to link to other experts (the "T" shaped person), as well as present the "check your discipline at the door" principle of the class. Usually on the first day we show a Nightline news story called the "Deep Dive" that followed an IDEO design team for a week [1].

We then introduce the particular design area with the help of a specialist in that area, which changes from course to course. For example, for the smart dorm room, we brought in staff from the Virginia Tech Assistive Technologies Lab to introduce the physical and cognitive nature of disabilities challenging their college student clients, and for the pet care project we brought in faculty from the College of Veterinary Medicine. The specialist helps establish the "higher-cause" that will begin student buy-in to the project. Whole group problem-seeking will immediately follow these presentations. Faculty recording the discussion on the board will be organizing comments under general headings. The students will choose a general heading to work under during the brainstorming stage that follows, as illustrated in Figure 6.

The students then present their brainstorm results as sketches or mockups to the class, and include their speculations on power, communications, materials, user behaviors, and human factors requirements. An example of the brainstorm sessions and mockups from the spring 2007 course are shown in Figure 7.

The presentation of brainstorm directions is followed by discussion and re-forming of teams based on interest and expertise [8]. The teams proceed to develop the projects through schematic sketches, computer models, and physical prototypes. Faculty are seeding entrepreneurial activities in this stage, which occupies most of the class time, by providing access to tooling, components, additional faculty or industry expertise, and by playing the role of both coach and critic, but always moving the project to the next level.

The amount of time we spend on each of these stages has varied from project to project. In the fall of 2010, we are planning to finish the research stage by the fourth week of the semester and have decided upon the set of products by the end of the sixth week. The remainder of the semester will then be spent developing the product designs, technical feasibility studies, and business plans. In the first several weeks of the course particularly, but also throughout the semester, we use the assignments for the various phases as opportunities to bridge gaps between disciplines. For example, if during the research discussion a student from one discipline says a word that might have one meaning within the discipline but another meaning in the other disciplines, we take the time to talk about these alternative meanings so that the students from each discipline can build a shared vocabulary. (Our discussion about the word "design" is often entertaining.)

Figure 6. Ed Dorsa records the brainstorming groups under the problem seeking headings.

Figure 7. From the spring 2007 interdisciplinary design project course on pervasive computing for improving safety on construction sites. Meg and Yan's brainstorm session.

Typically we have some form of outside evaluation of the students' work, either as a submission to an extramural student design contest or by creating a board of advisors. Final presentations to the project's board of advisors celebrate the work of the students and close out the course. The presentations session also begins the process of more detailed development in individual and team undergraduate and graduate thesis projects. Some of the projects from the courses have served as either senior theses for the industrial design students or as the basis for a master's thesis for the computer engineering students.

DISCUSSION

This section begins by describing the importance of space on the creative process. The section covers some of the mechanics of the course and then discusses factors in why the firefighter project was less satisfactory than other projects. It concludes by describe several areas for improving the course.

Process and space

Successful pervasive computing products require a balance of computing, design, and business expertise throughout their development phases [3, 4, 6, 9]. Without this collection of expertise, the product is likely to fall short in some critical technical, functional, or market requirement. The process for our projects is based heavily on the processes described in the references above, with due allowance for our teams being composed of senior/master's-level students rather than employees [5]. Some common elements of these design processes include cultivating a playful environment in which creativity can flourish, developing numerous options to choose from, prototyping early and often in a variety of mediums to help choose between options, and considering the user throughout the design process.

We believe that the value of interdisciplinary collaboration is at its apex during the concept generation stage, what some call the creative stage. Some believe that concept generation is about **how** to design something. But true conceptual thinking is actually better utilized and more valuable when focused on the opportunities of **what** to design. The discovery of the right thing to design is the real value of collaborative concept generation and it requires a more open ended approach and attitude than more traditional 'straight-line' methodologies. The interdisciplinary collaborative design process is more organic, more circular, as diverse ideas are freely discussed, merged with others, discarded, renewed and reframed. It is a replicable process only in the sense that an enabling environment of mutual respect, suspension of egos, and the consideration of possibilities unencumbered by discipline specific experiences can encourage it. It can be further encouraged by the physical environment and experienced participants who understand how to encourage creative group dialogue.

The creative stage of interdisciplinary product development should take place in an environment that not just allows but encourages participation from the entire team, thereby fostering creativity. Interdisciplinary corporate teams and university collaborators are investing considerable resources to improve the concept generation stage of the product development process, realizing that if they do not get the right "what" then all the expertise focused on "how" may be irrelevant.

Many of these groups have come to realize that physical space is a major qualitative factor in the process; that where concept generation happens is as important as the processes used to make it happen. They have explored dedicated spaces whose main purposes are to break down traditional barriers to communication and aid in concept generation. For example, the Stanford dSchool was created in part to serve as a 'neutral' space outside of the participating disciplines of Engineering, Industrial Design and Business so that 'home turf' advantages and 'disciplinary ownership' of the process could be minimized, if not eliminated. The space is designed for maximum organizational flexibility with easily movable furniture for grouping and re-grouping and vertical workspace, i.e., whiteboards on wheels that can be moved about as needed for sharing information. Our own experience after conducting several interdisciplinary product development classes over the last several years is that space is a major factor in the collaboration of the team and the quality of their work.

Course mechanics

Faculty at other institutions who are interested in running a similar course typically are interested in the mundane but nevertheless important mechanics of having a course that spans multiple colleges, particularly with respect to faculty loading, student credit, and student grades. We have covered many of these topics in an earlier paper [5], but we briefly summarize and update our thoughts here.

Faculty loading has been handled on a case-by-case basis. For one semester (construction site safety), we had the project listed as an actual course for the ECE students, but generally we have taught this as a collection of independent study projects. These independent study projects do not usually count toward our teaching load, so we have generally run the project as an overload. However, in at least one case we have received credit for a course by accumulating the number of students across several previous offerings of the course, which came to about the same number of students as a typical senior elective. In other cases we have received buyouts from an internal university program to cover our usual departmental courses. We have also had an instance when a faculty member was told by his department not to participate in the course, but he went ahead and participated anyway—but we had to ensure that we did not mention his participation in front of the wrong people.

In terms of student credit, most of the time this has been offered as three credit hours of elective, although this has varied with students' needs. In the PAwS project, the ID students were working on the project for seven credit hours. Usually we meet for three hours a week as a whole group (twice a week for an hour and a half), with assignments to individual teams that require them to meet outside of class.

Student grades are based upon their participation in class, their product concepts, and on their final designs and presentations, roughly in equal amounts. We try to reward the student's adoption of the process rather than only the quality of their final product, but this can sometimes be difficult (please see item 4 under the "Areas for improvement" subsection). Usually, everyone on a product team receives the same grade but not always, because student teams form and re-form through the course of the semester (i.e., a student might be on one team during the research phase and on a different team during the product development phase). The nebulousness of the grading rules are often more difficult for the engineering students to be comfortable with than the other students, because the engineering students are used to very explicitly defined grading criteria in their courses.

Factors in the dissatisfaction with the firefighter project

As stated previously, both the students and faculty were less satisfied with the firefighter project than with other projects. There are several factors that were different from the other projects, and we do not think that any one of them was the sole reason for the dissatisfaction.

First, instead of giving the students a broad area to investigate for product opportunities, we gave them a specific product to improve, the firefighter helmet. One outcome of this was that as the research stage progressed, students found related firefighter gear that could also be improved, thus making it difficult to stay focused on just the helmet.

Second, the course met once a week for a single three hour session rather than twice a week for two one-and-a-half hour sessions. This by itself was likely not an issue, but it had the side effect that when anyone had to miss a meeting because of another obligation, they missed a whole week's worth of work. The faculty in particular had a several week time span where at least one faculty member was traveling each week, which often meant that a large chunk of a meeting would be spent going over what had happened the previous week.

Third, and likely related to the faculty travel, we did not provide as much structure for and direction to the students as we had in earlier project [7], particularly early on when they were still getting to know how to work with each other. Our process is necessarily more non-linear and "seat-of-the-pants" than a typical course schedule, but it was much more so than in other projects.

Fourth, we did not set concrete goals for each discipline in the course [7]. We had targeted an industrial design student competition to submit the project designs to at the end of the semester. Thus the course focused on industrial design criteria and made the ECE and marketing students feel less necessary to the success of the project.

Finally, we had the students work as a whole group for longer, which we think discouraged communication and interaction [7]. We had only twelve students in the course, and let them work more or less as a whole group of twelve for several weeks. The previous two offerings had 21 students, which we immediately split into smaller more manageable teams. The PAwS project had only twelve students, but given the 10-week rather than 15-week schedule, we had more pressure to move into separate groups quickly.

Areas for improvement

We have identified several areas for improvement in running the course. We are actively working to address each of these areas in future offerings of the course.

1. *Replicating an industrial design team in an academic setting*. We teach the same process every time but to a new set of students. In industry, once a team is trained it would be able to build upon its previous experience, which is not possible in a senior-level course. We are trying to find a balance between the freshness of the course for the faculty while not overlooking topics that a student new to the process must experience. One way to mitigate this is by using a different product area with every offering of the course. But this has the downside of us not being able to build on the technical progress of previous courses.

2. *Dealing with the unfamiliar*. Engineering and marketing students are not familiar with being given an open-ended problem, whereas the industrial design students are. The industrial design students get little value out of the process because they have already had the experience in other classes, whereas the engineering students in particular are uncomfortable with it and might not see the value [7]. Most if not all of their prior course experience has been to be given a detailed product specification and being expected to build to that specification. We plan to address this by having the course go beyond product concepts to include prototype development.

3. Fitting within the university. We are trying to break out of disciplinary silos not only with the students in the class, but within the university's hierarchical structure. There are a number of low-level issues with running an interdisciplinary course across three colleges within a university system that is geared toward building up disciplinary silos rather than bridging between them. We have had bureaucratic issues with course approval forms and credit for the faculty teaching the course. Even something as mundane as scheduling a time for the course can be difficult when one program has its required senior courses in the afternoon and another has them in the morning, such that there is only a narrow window of time when students from both programs have an available time slot.

4. *Focusing on the process rather than the product*. It can be difficult for both students and faculty to realize that the

focus on the course is on the design process rather than on its outcome. Because the semester is so short there is too little time to iterate sufficiently on a concept, and thus the final products sometimes fall short in technical aspect. Within a single discipline, this would be a reason for student angst and for faculty to assign a lower grade, but when the focus is on the process rather than on the product, students should be rewarded for their achievements in working as part of a team. As an example of this, a student from one course was unhappy with the team and course dynamics when the product turned out to be less than desired. But that student got a job a short time later where the employer cited her experience in the interdisciplinary course as one of the deciding factors.

5. *Managing expectations for outcomes.* Closely related to the previous point is that we must not expect the students from one domain to become experts in the other domains, e.g., it is unrealistic to expect the computing and marketing students to have the same sketching skills as the industrial design students by the end of the semester . Our goal is for them to become able to understand the aspects of the product that their teammates in the other domains must deal with. This is not a minor in computer engineering for the marketing and industrial design students, or a minor in industrial design for the marketing and computing students. It is an introductory immersion that allows the students to become conversant in the cultures of the other disciplines.

6. *Providing intellectual tools for supporting the teams.* We must develop proper tools and abstractions that enable designers to focus on the form and function of pervasive computing products without having to deal with the complexities of the underlying technology. We must also provide a way to allowing the design students to have to deal with constraints that arise later in the design process when a product must move into manufacturing. To address these issues, in the fall 2010 offering of the course we will be introducing a toolkit of off-the-shelf (and hopefully easy-to-use) prototyping components based mainly on the Arduino project [2]. This should allow the students to move beyond product concepts to building prototypes within the 15 weeks of the semester.

CONCLUDING REMARKS

We believe that pervasive computing is a valuable area for teaching students about how to work in interdisciplinary teams. We believe that successful pervasive computing products must include computing, design, and business early in the design process. Consequently, it is important for students in each of those areas to understand the constraints imposed by the other areas and be able to communicate effectively across them. We are developing a senior-level undergraduate design experience that we hope is effective in giving students the interdisciplinary team skills they need to work in industry. We are evaluating and improving our process so that it can be used by faculty in other universities and other disciplines.

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