

Department Editor: Scott F. Midkiff ■ Virginia Tech ■ midkiff@vt.edu

# An Interdisciplinary Design Course for Pervasive Computing

*Tom Martin, Eloise Coupey, Lisa McNair, Ed Dorsa, Jason Forsyth, Sophie Kim, and Ron Kemnitzer*

## EDITOR'S INTRO

Pervasive computing is an inherently multidisciplinary and interdisciplinary field. This issue's column describes a multidepartment course where students learn about interdisciplinary design through pervasive computing systems. Your comments and suggestions for this column are welcome. Please contact me at midkiff@vt.edu.

*—Scott Midkiff*

Pervasive computing products must have an effective blend of technology, design, and business viability to succeed in the marketplace. Technology shortcomings reduce functionality, a poor design lowers the aesthetic appeal and reduces ease of use, and an ill-conceived business model can lead to product failure in the target market. All of these issues are true for any product family, but pervasive computing products include two added twists: product response is under computational rather than mechanical control, and the business model often depends on providing a service rather than selling a device. As a result, the primary challenge for creating successful pervasive computing products is to determine when and how each discipline should leverage its expertise for successful product development.

At Virginia Tech, we're in our sixth year of offering an interdisciplinary design course that gives undergraduates the interdisciplinary and technical skills required to design and develop pervasive computing devices.[1,2] The course has been developed and taught by a team of faculty from three departments: Electrical and Computer Engineering, Industrial Design, and Marketing. The team also includes a faculty member from the Department of Engineering Education who studies the processes that the class's interdisciplinary students follow as they form teams and work together.

## COURSE DEVELOPMENT

Creating a suite of pervasive computing products in an undergraduate class is challenging. We loosely model the class on the practices of leading product design firms, such as IDEO.[3] Such practices are widely accepted in industry and by many graduate programs in the US, but our program is unique among undergraduate programs. There's great value in introducing these methodologies to undergraduates to better prepare them for their professional careers.

We try to create a studio atmosphere similar to what would be found in a startup or small design firm, but we must work within constraints of being a university. Students have only a few hours a week to spend on the project, and they must complete it within the 15-week semester. More important, at first, the students don't know much about each other or the other disciplines, so we spend the first few weeks teaching the students to value the skill sets of students from the other programs. We try to bridge the cultural boundaries that exist between the programs in a university setting, helping the students build a shared vocabulary (for example, "model" has different meanings for engineering, business, and design students).

Also, we don't provide a product specification. Instead, we give them a "product opportunity area"—that is, an area in which a pervasive computing product could have a strong impact. The goal is to encourage creative thinking across disciplinary boundaries, which leads to product innovation. The students thus gain a unique and valuable experience as they determine the right specification instead of just meeting a predetermined specification.

Our product opportunity areas have included pet care for the elderly, construction-site safety, dorm rooms for students with disabilities, protective gear for firefighters, and diabetes management for children (see Figure 1). Students are free to develop any product as long as it falls within the product opportunity area and involves pervasive computing. Also, every team needs at least one student from each discipline. (For more on class development, see the "Quick Tips" sidebar.)



Published by the IEEE CS ■ 1536-1268/12/$31.00 © 2012 IEEE

## QUICK FACTS

**Course:** Independent study (ECE 4974 and IDS 4974) and honors undergraduate research (MKT 3104H)
**Units:** Electrical and Computer Engineering, Industrial Design, Marketing, Engineering Education
**Institution:** Virginia Tech
**Instructors:** Eloise Coupey (Marketing), Ed Dorsa (Industrial Design), Ron Kemnitzer (Industrial Design), Tom Martin (Computer Engineering), and Lisa McNair (Engineering Education)
**Level:** Senior-level undergraduate
**URL:** www.ece.vt.edu/tlmartin/interdisciplinary

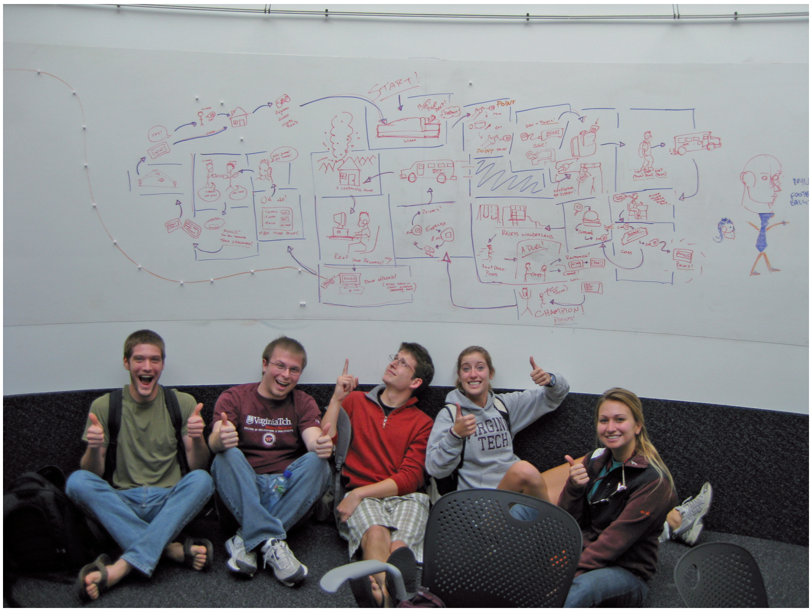

**Figure 1. A team from the 2010 course offering. This was after a long session in which the students developed a storyboard of a game that rewards children with diabetes who follow their treatment regimen.**

## COURSE OUTLINE

When we first started working together, our main focus was on the products. We quickly realized, however, that the process we were following was at least as important as the students' final designs. At that point, we brought in a faculty member from engineering education to help us improve our process. This participation, coupled with feedback from students, led us to include several aspects in the process that have enhanced the experience of the students and the quality of the products they produce.

### Interdisciplinary Introduction

During the first week of the semester, we give the students an overview of each of the three disciplines and describe the product opportunity area. We then divide the students into research teams, with one student from each discipline on each team. These research teams explore the issues related to the opportunity area, identify key stakeholders, and review existing products.

During each class meeting, we have each team discuss their research with the rest of the class. Based on these discussions, we then give them more detailed research assignments. For example, after identifying groups of stakeholders, we might assign each student team a different stakeholder group for further research.

### Research

The research phase of the course lasts about five weeks. Near the end of this phase, the students begin proposing product ideas. We brainstorm for one week, and then, depending on the class size (we typically have 21 students total, seven from each program), we have the students pick four or five product ideas for development.

The student teams then re-form around the selected products. We try to let the students choose their product, but if there's a team without an engineering student, for example, we'll encourage an engineering student to change teams. We also try to balance the team size with the product complexity, so teams range from three to five students.

### Product Development

The rest of the semester is spent developing the product. The final deliverable is a short presentation to a group of local venture capitalists. The students must develop an integrated product document and presentation that covers their product's business, design, and technical aspects. The students only have a few weeks, so they don't have to complete product development; we just expect sufficient development to convince someone of the product's potential. For example, we don't require a fully working prototype for the final presentation. Rather, the students must provide a prototype that convinces others of the product's viability and technical feasibility.

During product development, we give the students hands-on exercises for each discipline. For example, for one marketing exercise, the students create the product box for store shelves, and for one of the computing exercises, students use an Arduino kit to develop

EDUCATION & TRAINING

## QUICK TIPS

Colleagues have often asked us for a concrete list of "do's and don'ts" for running an interdisciplinary design course. Here's a list of essential but easy-to-overlook details.

### Find Like-Minded Faculty

Actively search for people who want to work across departmental and college boundaries. Having a like-minded set of faculty will help set the classroom's tone. Also, be open to serendipity—the first person you approach might not work out, but he or she could lead you to someone else.

### Find Appropriate Space

Ideally, the space should be dedicated to just your project, so students can leave materials behind and meet there in small groups outside of normal meeting times. If your space is clearly in one department, be sure to make the students and faculty from the other departments feel an equal sense of ownership. Otherwise, they might be reluctant to participate. Also, the space should be playful and encourage creativity.

### Build a Community

Provide opportunities for students to get to know each other—particularly the students from other programs. This will help build a shared responsibility for the course outcome as the students begin to bridge the cultural gaps between disciplines, particularly bridging the vocabulary differences.

### Promote Students' Expertise

Activities that require students to experience other disciplines can also encourage students to practice their own disciplinary expertise by acting as guides. For example, have each group give a short demonstration after an exercise. The person leading the demonstration should be someone from outside the main area of the exercise. So, if you're doing a marketing exercise, ask one of the marketing students to guide the exercise but then ask a student from another discipline to demonstrate the group's work to the rest of the class.

### Serve as a Role Model

The faculty should have open and frank discussions about the project in front of the students, modeling the professional behavior that's expected in student teams. Seeing the faculty work through a point of disagreement is probably more useful for the students than seeing the faculty get along all the time.

### Provide Structured Freedom

Let the students take charge, but provide enough structure so they don't feel lost.

### Set up Discipline-Balanced Projects

If a final deliverable is heavily weighted toward one discipline, the other students will feel they have little influence, while the central-discipline students won't learn anything new. One of our worst projects involved a final deliverable that was an entry in an industrial design contest. The project was heavily tilted toward ID, so the engineering and marketing students had little to do, while the ID students felt the class wasn't much different from other ID classes. We've remedied this by making the final deliverable a six-minute pitch that should convince local venture capitalists that all three aspects of the product (design, technology, and business) are sound enough for product success.

### Expect the Unexpected

An open-ended design course might seem easier to prepare for than a more typical class—you don't need to create lectures or grade homework or exams. However, you still need to prepare, especially for the in-class discussions. The students will surprise you, providing unexpected feedback and requests. The class is a form of improvisation; you must closely listen to the students and provide thoughtful and thought-provoking responses.

### Have a Flexible Design Process

We have a set of common design steps at our disposal, but we don't go through them in the same order for each class. For one project, the order might be *ideation, synthesis, prototyping, research*, and *visualization*, while for another, the order might be *research, ideation, visualization, synthesis*, and *prototyping*.

### Develop Mantras

Summarize the philosophy of the design team in easy-to-remember phrases. We have several mantras, some borrowed, some original: "Check your discipline at the door,"[1] "Be a T-shaped person,"[1] "Encourage wild ideas,"[1] "Be innovative, not flamboyant," and "There are never any answers, only choices."[2]

### REFERENCES

1. T. Kelley and J. Littman, *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm*, Doubleday, 2001.
2. J. Williams, *The Art and Science of Analog Circuit Design*, Butterworth-Heinemann, 1995.

an interactive toy. These exercises serve three main purposes. First, they give the students a better idea of what's expected of their final deliverables. Second, and more important, they give the students a better understanding of the capabilities and responsibilities of the other disciplines and help build the shared vocabulary and a shared sense of responsibility. Finally, team members get a chance to demonstrate their expertise while coaching their teammates through the exercise in their particular discipline.

We treat the students of each discipline as a consulting firm that has been hired out to the product team. Each student is both a member of a product team and a disciplinary firm. Thus, if an engineering student on a product team needs help, that student can go to the other engineering students for advice. This helps build the sense of shared responsibility for the course's success.

We also ask students to define the relationships between the products. Products within the same opportunity area can often be viewed as a product family—each individual product can be used alone, but it has greater value to the customer when used with other products in the family. We have the students identify closely related products, and each team then assigns a liaison who's responsible for the relationship between a pair of products.

## PRODUCT CHALLENGES SPECIFIC TO PERVASIVE COMPUTING

Most of the interdisciplinary aspects of the course would be true for any course involving students and faculty from multiple colleges or any integrated product design team, but our course addresses the challenges specific to pervasive computing products.

### Computational vs. Mechanical Control

As noted earlier, a pervasive computing product's response to use is under computational rather than mechanical control. This has major consequences for our students, particularly as new materials become available with physical properties that can change dynamically.

To illustrate the impact these materials have on designers, consider the difference between the steering mechanism on an early automobile and today's drive-by-wire automobiles. On the first automobiles, there was a direct physical link between the steering wheel and the wheels. The response of the wheels to a turn of the steering wheel was fixed at design time. In contrast, with today's drive-by-wire systems, it's possible to have the steering response depend not just on how much the steering wheel is turned but also on the conditions in the car and the surrounding environment, so the response can dynamically adapt.

So it is with pervasive computing products, which can use sensing capabilities and an ability to network with other devices such that the product can adapt itself to the user, the current context, and the use history. Pervasive computing will eventually enable a form of mass customization that's not yet possible.

### The Service Component

Pervasive computing products also tend to involve a service component rather than a more traditional, tangible item. Students work closely with the other disciplines to identify how technology enables the products to interact, providing benefits that go beyond standalone performance. Given the often-invisible nature of the technology (for example, through computational control), however, students must create marketing and business plans that can identify target customers, position the service, and effectively communicate the service's benefits.

Our course has been well received by students and by our colleagues both in industry and at other universities. Several of our students have remarked that the course helped them find a job, and one of our teams won the top prize in the medical products category of an entrepreneurship competition. We have an advisory board with members from academia and industry, who have provided us with valuable feedback and encouragement. Local venture capitalists have also given us positive comments after participating in our students' final presentations.

We're currently working with two other universities, one in the US and one overseas, to adapt our class for their programs. We hope this article will encourage other institutions to provide similar experiences for their students. ■

## ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under Grant No. EEC-0935103.

## REFERENCES

1. T. Martin et al., "An Interdisciplinary Undergraduate Design Course for Wearable and Pervasive Computing Products," *Proc. 15th Int'l Symp. Wearable Computers*, IEEE CS Press, 2011, pp. 61–68.
2. E. Coupey et al., "A Case Study of an Interdisciplinary Design Course for Pervasive Computing," *Proc. Third Workshop on Pervasive Computing Education*, 2010; http://mmis.informatik.uni-rostock.de/images/PerEd2010_-_Coupey_Dorsa_Kemnitzer_McNair_Martin_-_Interdisciplinary_Design_Course.pdf.
3. T. Kelley and J. Littman, *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm*, Doubleday, 2001.

**Tom Martin** is an associate professor of computer engineering at Virginia Tech. Contact him at tlmartin@vt.edu.

**Eloise Coupey** is an associate professor of marketing at Virginia Tech. Contact her at ecoupey@vt.edu.

**Lisa McNair** is an associate professor of engineering education at Virginia Tech. Contact her at lmcnair@vt.edu.

**Ed Dorsa** is an associate professor of industrial design at Virginia Tech. Contact him at dorsa@vt.edu.

**Jason Forsyth** is a doctoral student at Virginia Tech. Contact him at jforsyth@vt.edu.

**Sophie Kim** is a doctoral student at Virginia Tech. Contact her at kahyunk@vt.edu.

**Ron Kemnitzer** is a professor of industrial design at Virginia Tech. Contact him at rkemnitz@vt.edu.