An undergraduate interdisciplinary design course for pervasive computing

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Pervasive computing products must have an effective blend of technology, design, and business viability to be successful in the marketplace. Shortcomings in technology result in a lack of functionality; poor design leads to a lack of aesthetic appeal and ease-of-use; and an ill-conceived business model means that the product fails in its target market. While all of these issues are true for any product family, with pervasive computing there are two added twists that make them even more important: The response of the product to the user 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.

For the past five years at Virginia Tech, we have run an interdisciplinary design course for pervasive computing products, with the goal of providing undergraduates with the interdisciplinary and technical skills for designing and developing 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, leading the course, with advanced undergraduate students from those programs. We also have a faculty member from the Department of Engineering Education on the team studying the interdisciplinary teaming processes that occur in the class.

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]. Those practices are widely accepted in industry, and by many of the better graduate programs in the U.S., but our program may be unique among undergraduate programs. Thus we believe there is great value in introducing these methodologies to undergraduates so that they can be better prepared for their professional careers. While we try to create a studio atmosphere similar to what would be found in a startup or small design firm, we face the constraints of being in a university. For instance, students have only a few hours a week to spend on the project, and we have only a 15-week semester to complete the project. The major difference, however, is interpersonal; students do not know each other at the beginning of the project, and they are unfamiliar with the expertise of the other disciplines in the course. Consequently, we spend the first few weeks of the semester teaching the students to understand and value the skill sets of the students from the other programs. We try to bridge the cultural boundaries that exist between the programs in a university setting, helping the students to build a shared vocabulary (for example, the word “model” has different
Another major characteristic of the course is that we do not start the project by giving the students a specification of the product they will develop. Instead, we give them a “product opportunity area” where there is a large potential for a pervasive computing product to have an impact. The goal is to encourage creative thinking – across disciplinary boundaries – that leads to product innovation. In contrast to most, if not all, of their other courses, our students gain valuable experience in figuring out the right specification, rather than just how to meet a predetermined specification. Our product opportunity areas have included pet care for the elderly; safety on construction sites; dorm rooms for students with disabilities; protective gear for firefighters; and diabetes management for children. Students are free to develop any product of their choosing, as long as it falls within the product opportunity area and involves pervasive computing. We also require that every team has at least one student from each discipline.

When we first started working together, our main focus was on the products. We quickly realized, however, that the process we were following was just as, and probably more, important than 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.

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 them up 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 upon 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.

The research phase of the course lasts about five weeks. Near the end of the research phase, the students begin proposing ideas for potential products. We use one week to brainstorm product ideas. Depending upon the class size (we typically have 21 students total, 7 from each program) we have the students pick four or five product ideas for development. The student teams then re-form around those products. We try to let the students choose which product they will work on, but we continue to insist that each team has at least one person from each discipline. If there is a team without an engineering student, for example, we will strongly encourage an engineering student from another team to change teams. We attempt to balance the size of the teams with the complexity of the product, so product teams range from three to five students.

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 are required to develop an integrated product document and presentation that covers the business, design, and technical aspects of their product. The product development does not have to be complete; because the students only have a few weeks, we expect sufficient development to convince someone of the product’s potential. For example, we do not require that the students have a fully working prototype for their final presentation. Rather, they must provide a
prototype that demonstrates the product concept well enough to convince others of the product’s viability and technical feasibility.

During the product development phase, we give the students hands-on exercises in each of the disciplines. For example, we have a marketing exercise where the students have to create the product box that will be on store shelves, and we have a computing exercise where the students use an Arduino kit to develop an interactive toy. The exercises serve three main purposes: First, they give the students a better idea of what is expected of their final deliverables. Second, and more importantly, the exercises give the students a better understanding of the capabilities and responsibilities of the other disciplines on their teams, and they build the shared vocabulary and shared sense of responsibility of the team. Finally, team members in the discipline of the exercise get a chance to demonstrate their expertise while coaching their teammates through the exercise.

During the product development phase of the course, 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 of a disciplinary firm. Thus, if an engineering student on a product team requires help, that student can go to the other engineering students for advice. We believe this helps to build the sense of shared responsibility for the success of the course.

Another aspect we emphasize during the product development phase is that the students should define the relationships between the products. Because the products are within the same opportunity area, they can often be viewed as a product family, in which each individual product can be used alone, but has greater value to the customer when used with other products in the family. We have the students identify the products that are closely related to each other. Each team then assigns a liaison to be responsible for the relationship between a pair of products.

Finally, 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. However, we believe that pervasive computing products have two aspects that set them apart from other products, noted at the beginning of this article. First, the product’s response to use is under computational control rather than mechanical control. Having the product’s response be under computational control has major consequences for our students, particularly as new materials become available that can change their physical properties dynamically. As an analogy, 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 linkage 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 is possible to have the steering response depend not just on how much the steering wheel is turned, but on the conditions in the car and the surrounding environment, so that the response can dynamically adapt. So it is with pervasive computing products, which can take advantage of sensing on the device and networking to other devices to adapt themselves to the user, to the current context, and their history of use. We believe that pervasive computing will enable a form of mass customization that has not been possible before.

The second characteristic of pervasive computing products is that they tend to involve a service component, rather than just a more traditional, tangible item. Students work closely with the other disciplines to identify the ways in which technology enables the products to interact, providing benefits
that go beyond standalone performance. Given the often-invisible nature of the technology (e.g., through computational control), however, students must create marketing and business plans capable of identifying target customers, developing the product positioning, and creating effective media plans that can accurately and compellingly communicate the benefits of the service product.

Our course has been very well received by our students and our colleagues in both industry and other universities. Several of our students have remarked that the course helped them to 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, which has provided us with valuable feedback and encouragement. Local venture capitalists have also given us positive comments after participating in our students’ final presentations. Finally, we are currently working with two other universities, one in the U.S. 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.

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References:


SIDEBAR:

Tips for running an interdisciplinary design course.

Colleagues have often asked us for a concrete list of “do’s and don’ts” for running a course like ours. Here is a list of essential but all too easy to overlook details.

1. Find a like-minded set of faculty. Actively search for people who want to work across departmental and college boundaries. Having a like-minded set of faculty is important to set the tone in the classroom. Also, be open to serendipity – it might be that the first person you start working with doesn’t work out, but that contact will lead you to someone else.

2. Find an appropriate space for the project. Ideally the space is dedicated to just your project, so that students can leave materials behind after every meeting and so that they can meet there in small groups outside of the normal meeting time. 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. If they feel like guests, even welcome guests, that might make them reluctant to participate and unlikely to feel at ease. The space should be playful and encourage creativity.

3. Build community. Provide opportunities for students to get to know each other, particularly the students from the other programs. These opportunities should serve several purposes: as the students get to know each other personally, they begin to build a shared responsibility for the outcome of the course, and they begin to bridge the cultural gaps between disciplines (particularly language).

4. Encourage students as experts. Activities that require students to experience the other disciplines on the project can also encourage each student to practice their disciplinary expertise as guides. One way to make sure this happens is to have each group give a short demonstration after the exercise and make the person giving the demonstration be someone from outside the area of the exercise. For example, if the exercise is in marketing, have the marketing student guide the exercise within the group, but then have one of the non-marketing members in the group give the demonstration of the group's work to the rest of the class.

5. Have the faculty serve as role models for the students. The faculty should have open and frank discussions about the project in front of the students, modeling the professional behavior that is expected within the student teams. This does not have to be "all-touchy-feely-everybody's-happy-all-the-time" –
seeing the faculty working through a point of disagreement is probably more useful for the students to see than the faculty simply agreeing with each other all the time.

6. Teach (and let) the students take charge while providing enough structure so that they don't feel lost.

7. Set up discipline-balanced projects. If a final deliverable is heavily weighted toward one discipline, the other students will feel like they have little influence and the central discipline students will feel like they’re not learning anything new. A balanced deliverable includes learning for everyone, like a 6-minute pitch to local venture capitalists that requires convincing them that all three aspects of the product (design, technology, and business) are sound enough that the product could be successful. For example, probably our worst project was one where the final deliverable was an entry into an industrial design contest. With the project tilted so heavily toward ID, the engineering and marketing students felt they had very little to do and the ID students felt like they didn't learn anything new because they were doing basically the same things that they did in their other ID classes. We've remedied this by making the final deliverable be a 6-minute pitch to local venture capitalists that requires convincing them that all three aspects of the product (design, technology, and business) are sound enough that the product could be successful.

8. Be prepared to deal with the unexpected. An open-ended design course might seem easier to prepare for than a more typical class—there are no lectures to create, no homework or exams to grade. But such a design course requires a different kind of preparation that is equally difficult before class and probably more difficult in class. The students will surprise you every day, giving you feedback and requests that you will not be able to anticipate. Instead of a lecture, it's much more a form of improvisation where you must listen deeply to what's being said by the students and build upon it with your response.

9. Have a flexible design process. While there might be a set of generally common design steps at our disposal, we don't go through those steps in the same order every time. For one project, the order of our steps might be ideation, synthesis, prototyping, research, visualization. Then the next time it might be research, ideation, visualization, synthesis, prototyping.

10. Have mantras: Summarize the philosophy of the design team in easy-to-remember phrases. We have several, some we’ve borrowed from elsewhere [3, 4] and some we’ve made up: Check your discipline at the door. Be a T-shaped person. Encourage wild ideas. Be innovative, not flamboyant. There are never any answers, only choices.