

Computing in Context: Integrating an Embedded Computing Project into a Course on Ethical and Societal Issues

Fred G. Martin
University of Massachusetts Lowell
Department of Computer Science
Lowell, MA 01854
fredm@cs.uml.edu

Sarah Kuhn
University of Massachusetts Lowell
Regional Economic and Social Development
Lowell, MA 01854
Sarah_Kuhn@uml.edu

ABSTRACT

A hands-on embedded computing project is introduced into an undergraduate social sciences course. In the pilot module, nine student teams created working prototypes, using the technology to address social, ecological and ethical issues. The teams included freshman to senior level computer science majors, other technical majors, and non-technical students. Most students became highly engaged in the activity, developed exciting ideas, and reported improved learning in the social sciences.

Categories and Subject Descriptors

K.3.2 [Computers and Education]: Computer and Information Science Education—*computer science education, curriculum, literacy*; K.4 [Computers and Society]: General

General Terms

Design, Human Factors

Keywords

Ethical/Societal Issues, Active Learning, Non-majors, Gender and Diversity Issues, Pedagogy, Robotics, Sustainability

1. INTRODUCTION

This paper describes the authors' experience introducing a hands-on embedded computing project module into an undergraduate social science course. To introduce embedded computing, we used the "Handy Cricket," an inexpensive, hand-held robotics controller. Students added sensors, actuators, and their own small control programs.

The students were a combination of Computer Science (CS) majors, engineering students, and non-technical majors. Our goal was to allow students to explore the key

themes in the class—social, environmental, and ethical issues—by creating computationally active product and concept prototypes. We also hoped to introduce an active, "can-do" form of computing literacy to the non-technical majors.

2. THE COURSE MODULE

2.1 The Course

Sustainable Development has been offered regularly since the late 1990s and satisfies the Behavioral Science General Education requirement for UMass Lowell undergraduates. Soon after its inception, it was also approved by the Computer Science department as a course that would satisfy the ethics requirement for CS majors. The course involves extensive reading and discussion about many aspects of sustainability: environmental toxins, electronic waste, occupational health, urban sprawl, green design, corporate governance, professional ethics, and others. In the Spring semester 2005, when we introduced the computing module, enrollment in the course was limited to 20, because of laboratory space constraints. Half of the students were CS majors; the rest were a diverse group including business, social science, and engineering majors.

The project module began $3\frac{1}{2}$ weeks before the end of the semester, after students had spent several weeks engaged in reading and discussion. In our instructions to students, we said: "*You will work with a partner to create a device or construction linked to one or more of the topics of this course. Your device should in some way either a) address a problem or issue from the course or b) assist in collecting data to better understand a problem or issue.*" We asked students to send us an email after the first week of the module telling us what sort of device they planned to build. In addition to creating a prototype device, students were required to prepare a trifold "display board" with descriptive and background information about their device, and to complete two short, reflective writing assignments. The final class of the semester was an open house to which the entire university community was invited, at which the students presented their work informally to visitors.

2.2 The Technology

The course module was based on the "Handy Cricket," a small low-cost embedded controller designed for rapid development of interactive prototypes (Figure 1). The Handy

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Figure 1: The Handy Cricket.

Cricket has been used with children and teachers for robotics and science experiments [6] and with non-technical professional designers [7].

The Cricket unit is a self-contained, battery-powered microprocessor board with sensor and motor circuits. It is programmed using “Cricket Logo,” a simplified dialect of the pedagogical Logo programming language [8]. Cricket Logo is a procedural language that includes functions with arguments and return values, global variables, control structures, and I/O primitives for the sensors and actuators.

In the context of the Sustainable Development course, we provided each student team (of 2 to 3 members) with complete kits built around the Handy Cricket. The kits included various sensors and actuators. For sensors, each team received a touch sensor, ambient light sensor, and temperature sensor. For actuators, teams received a simple DC motor and a small incandescent bulb. We also had several units of more specialized components that were available to the class, including a bar code reader, a pH sensor, a barometric pressure sensor, and voice recorder/playback modules.

In addition to the kits, we purchased a supply of craft and construction materials and hand tools that were made available for students. We also provided 24×7 access to a dedicated teaching laboratory for students to conduct their work; each team had its own benchtop work area that included a development PC.

2.3 Research Methods

We used a mix of qualitative and quantitative techniques to study students’ reactions to the course module. Qualitative techniques included: 1) observation of student work sessions by a graduate research assistant and the authors; 2) analysis of two writing assignments prepared by each student (one reflected on the project module after its completion, and one reflected on the overall course experience); 3) observation of the open house. Quantitative methods involved tabulation of student answers to a short questionnaire. The small number of students in this first iteration of the module precluded the use of statistical tests, but student answers helped in understanding students’ experiences.

3. RESULTS

Table 1 lists an overview of each of the 9 projects developed by the students in the course module. Both we and the students were impressed with the breadth and creativity that these projects represent.

3.1 Central Ideas in Computing

In each of the projects, students created a device or system that included inputs (sensors or buttons to be pressed), outputs (actuators, lamps, or other displays), and a control program. The control program was responsible for making the device exhibit some behavior, implement an algorithm, or otherwise perform its function.

Each of the projects thus exhibited the central idea of computing: a self-controlled process that works on inputs and produces outputs. In fact, the projects embody a more modern view of computing than the earlier, but still prevalent, idea of an algorithm that runs once to completion. This newer model of “computation-as-interaction” is described by Stein in her work on rethinking the CS curriculum:

Perhaps the most fundamental idea in modern computer science is that of interactive processes. Computation is embedded in a (physical or virtual) world; its role is to interact with that world to produce desired behavior. While von Neumann serial programming has it that computation-as-calculation uses inputs—at the beginning—to produce outputs—at the end—computation-as-interaction treats inputs as things that are monitored and outputs as actions that are taken over the lifetime of an ongoing process. [9]

While we did not focus instructional attention on models of computing, many students did reflect on the technical dimension of their work. For many of the CS students, the project was an opportunity to put their existing expertise with computing into practice, connect it with ideas in other fields, and to carry out their own “mini capstone” project.

We provided support for all students who needed it, especially non-majors. For these students, programming and engineering design were very new. In general, these students had a positive attitude afterward. As one student commented, “I was most surprised by my interest in robotics and computer science. . . it is a new area for me, but I enjoyed the experience.”

For all students, computing was connected to the real world in both a practical sense (their projects used embedded computing) and in an applied sense (they created a meaningful prototype).

3.2 Integrating Social and Ethical Issues with Computing

Computer science majors in the United States take courses in ethics and the social sciences, but these are typically separate from their CS courses, and are generally taught by instructors in other departments. This can make it difficult for students to integrate their social and ethical training with the material they learn in their CS courses, creating the impression that there is no relationship between social and ethical problems and the discipline of Computer Science. At best this is a missed opportunity; at worst it can cause considerable distress to students who take both the techni-

Project Title	Description	Comments
Reforestation Rover	A tree-planting mobile robot that surveys soil & environmental conditions and plants a seed when conditions are favorable	The robot was built out of LEGO bricks and performed on a tabletop, but was able to eject glass marble ‘seeds’ based on sensor values
Passive Cooling Dollhouse	An A-frame model house with an acrylic side view panel, and a floor-mounted fan. In the basement, an ice-pack modeled a cool temperature source, and the Cricket controlled the fan with a temperature sensor	The students who built this were non-technical, did a lot of decorative work and required hand-holding on the technology side, but ultimately persevered and were happy with the work
pH Power Boat	A radio-controlled model boat that carried a pH sensor and a bargraph display to show water pH. The bargraph was designed to be visible from a good distance	You would use the boat to investigate waterborne environmental incidents
Corporate Responsibility Product Scanner	A hand-held device with an integrated barcode scanner. After scanning a consumer product, it performs a database lookup and displays a ranking of the manufacturer’s corporate responsibility along several scales	The prototype simulated the database lookup, but was pre-programmed for several product barcodes on hand at the open house
Personal Waste Scale	An office trash basket with an integrated weight scale. It weighed your trash and indicated the result on an LED numeric display	Project was accomplished by repurposing the innards of a \$15 bathroom scale
Trucker Awake Project	Model truck that sensed abrupt changes in velocity and responded with a light show visible both inside and outside the truck	The idea was to provide feedback to both the driver and law enforcement, raising interesting questions about accountability
Ecological Footprint Quiz Machine	Based on a web survey, this was a standalone device in which you answered a series of questions. It reported how many Earths would be needed to support the population, if you represented the average world citizen	Students built a large vertical “carnival wheel” in which you rotated to each question and pressed a button corresponding to your answer. The Cricket sensed the position of the wheel and scored your survey accordingly
Audio Light Quality Alarm	Measured ambient light level and warned with an audio alarm if levels were too bright or too dim for healthy office work	Project was accompanied by literature review of lighting and health
Cricket Thermometer	Inspired by the actual cricket insect, which varies its chirping based on temperature, this project provided several modalities for conveying temperature, including spoken output	The idea was to provide an interactive thermometer for the visually handicapped

Table 1: Synopsis of Student Projects.

cal and the social material seriously, leading to a sense that they must choose between social and technical concerns [3].

By introducing computing into a course committed to exploring environmental, social, and ethical issues, students have an opportunity to integrate the material in an active and creative way. With guidance from faculty in both the social and computer sciences, the connection of the disciplines takes place at many levels during the course. Students become motivated to address important real-world problems and think about how digital technology could contribute to solutions. The iterative process of framing and reframing approaches, guided by the instructors and by conversations with fellow students in the lab, demonstrates how designers can move easily between social and technical concerns in a fluid design process [1, 4].

3.3 Triangulating Between Course Themes, the Materials, and Their Ideas

In their design processes, students went back and forth across the themes of the course, the capabilities of the Cricket and the other materials we had provided, and their own ideas about what they would like to create. For example, in the early stages, some students became fixated on the sensors

we had offered them. “At one point in the course, I thought we were all going to be making PDAs that measure water temperature and pH,” said one student.

By asking them to step back and consider which course topics had been their favorites, and what problems associated with those topics they might want to tackle, we were able to get them to take a broader view and find some convergence between the social and ethical problems they had studied and the materials they had at hand.

One student pair was interested in corporate social responsibility, and discussed approaches to rating companies’ degree of commitment to their stakeholders. They developed a handheld device with an integrated barcode scanner that could identify products from their barcode, and then deliver information from a hypothetical database about the social responsibility of that product’s manufacturer (Figure 2). Another group was interested in the “ecological footprint,” a system that rates an individual’s environmental impact by posing a series of questions about lifestyle and habits. They created a device that allowed visitors to take the quiz in real time (a true design challenge, given the limited display capabilities of the Cricket).

By integrating computing with other disciplines and with



Figure 2: The Corporate Responsibility Product Scanner.

social concerns, the course module not only modeled ethical practice for computer scientists, but exposed non-majors to the ways in which computing can contribute to society and to the quality of life. Furthermore, this approach can better prepare many students for computing careers, which increasingly involve uniting an understanding of computing with knowledge from other disciplines or occupations [5]. Finally, introducing students to areas which represent the intersection of computer science with other disciplines—biology, chemistry, business, planning, etc.—may be a more effective way to attract and retain nontraditional students, particularly women [10].

3.4 Active Learning in a Multidisciplinary Context

We expected that the hands-on module would improve students’ understanding of sustainable development, and in a survey taken at the end of the course, most students agreed that it had had this effect. Several of them told us, however, that the most important impact was to make them feel that they could play an active role in addressing the problems of sustainability. Although we had in-class discussions and had considered solutions to some of the environmental and social problems reviewed in the course, students said that it was really the project module that turned them from passive consumers of information into active shapers of solutions. “It brings a sense that you are participating in solving the problems, rather than just learning about the problems and possible solutions in class,” said a freshman liberal arts student. “[I]n introducing the concept of helping towards a more sustainable future, I believe that we will be more likely to do so in the future,” he added.

The students’ sense that they can become active moral agents [11] is probably more important to their development as responsible practitioners than any other single lesson they could have learned in the course. The module introduced CS students to one model of responsible professional practice, while non-majors learned that it is possible to address social and ethical issues actively, including through the development of devices with embedded computation.

Although almost everyone complained about how little time they were given to plan and execute their device, many

said they were very pleased with what they accomplished, and most, when asked what most surprised them about the project module, commented admiringly on the variety and creativity of their fellow students’ projects. “[I]t has taught me the value of brainstorming,” said one CS major. Students also learned how much they and others could accomplish in a very short period of time—and the ability to work quickly to skillfully solve a problem is an important component of expertise [2].

3.5 Mixing Majors and Non-Majors in a Single Class

It is striking that students from a wide variety of majors, and at different undergraduate levels (from freshman to senior) felt the course module was a successful experience for them, to the extent that all but one of the respondents to the questionnaire agreed that the module should be a permanent part of the course (the one dissenter was undecided). Some individuals and teams needed more technical support than others, but all teams managed to produce a device that satisfied the requirements of the assignment, and visitors to the open house praised the products.

The team with the least technical background consisted of two female business majors who decided to build a model house and use the Cricket and a temperature sensor to control a fan. One of the partners said, “I was honestly dreading doing the hands-on module... sometimes I do not understand how to use things that involve technology.” The other was more enthusiastic, saying “I was really excited because I enjoy creative projects.” Neither seemed to have much experience thinking about the mechanisms that underlie everyday technology; for instance, when they decided to incorporate a fan into their project, they built a fan with paddles that laid flat, rather than raking into the air.

The team had no prior programming experience. To help them get their project running, we walked them through an introduction to programming. The final implementation involved just one line of code, transforming the fan motor and temperature sensor into a thermostat. But, this single line made perfect sense to the students, and gave them great satisfaction as they saw the fan motor turn on and off based on the house’s temperature. While the project was less technically sophisticated than many of the others, for these two students it was a significant accomplishment.

In their evaluations, students also stressed the non-cognitive benefits of the course module—it engaged their interest and enthusiasm, and created “class-wide camaraderie,” in the words of one student, as they worked side by side on their projects, helping one another to learn and solve problems. Competition between students was lessened because each team was working on a different project of its own design, and because, for this first-time experimental module, we told students that their grades were based on lab attendance alone, meaning that in theory every student could get an “A” for this segment of the course.

3.6 Role of Technology in Students’ Projects

A range of themes emerges from the students’ projects, with three different notions about the role of technology:

Reflecting some aspect of human behavior back to ourselves, allowing us to consider changing it. Four projects are based on this principle: the Corporate Responsibility Product Scanner, the Personal Waste Scale, the

Ecological Footprint Quiz Machine, and the Trucker Awake Project. In each of these, the concept involves allowing us to perceive something about our own behavior that we would not normally notice, allowing us to consider changing our habits.

Technology that reveals something to us that otherwise would be hidden. Three projects are based on this idea: the pH Power Boat, the Audio Light Quality Alarm, and the Cricket Thermometer. These projects are instruments that allow us to better perceive the world.

Systems that autonomously improve the world. In two projects, self-controlled technology is to be installed into the world: the Passive Cooling Dollhouse and the Reformation Rover. Both represent aspirations for technology to improve the environment.

This group of approaches is provocative and will warrant further attention as we revisit course themes in future versions of our course.

3.7 On Creating and Exhibiting a Prototype

In creating a working product (their concept prototype), students were required to use different skills than those exercised by more typical assignments such as a term paper or class presentation. All of our students realized (1) they would have to show off their project at an open house, and (2) the prototype would have to *do something*.

These dimensions had a profound impact on some of our students. With respect to building the prototype, a student noted that “it’s actually the only hands-on project that I’ve been able to do these past four years at UMass Lowell.” On the public exhibition, another student said “I was very happy with the open house because I have never had to do anything like that before and it felt so professional.”

We also noted the energy and enthusiasm that most students invested in their projects; the lab space was well-used as the open house neared. One of the CS students commented that “this is really the first project I have had where the groups really did get together and even interact with the other groups in working on their projects.”

Indeed, the projects seemed to carry students aspirations and hopes along with them. Even though they were all just lab prototypes, students thought of them as real-world projects. At the open house, we were impressed with students’ confidence in presenting their work and discussing it with visitors; it was clear that students were proud of their work.

4. CONCLUSION

One of our students noted that “trying to make something sustainable with the electronics I felt was a little arbitrary, and the most difficult thing would be coming up with a project idea that was viable and actually could have been considered sustainable.”

Although we expected that the project would deepen students’ knowledge of sustainable development, students also reported a more important outcome: the experience of the project convinced them that they could become active problem solvers, and could create actual solutions to sustainable development problems.

These are both crucial points. While it was the two authors’ interests that brought these worlds (sustainable development and embedded computing) together, we now see strong evidence that it is a productive marriage.

And, like our students, we were thrilled with the class’s creativity in coming up with innovative ideas as to how these two realms can support each other.

Based on the students’ evident enthusiasm, thoughtful written feedback, and the work itself, the activity was highly successful in engaging students with ideas in the social sciences field, and providing them a forum to exercise or develop technical expertise. We are very encouraged by the results of the pilot and are planning continued work, including the development of a new version of the course that includes semester-long project work.

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