A Graduate/Senior Level Interdisciplinary Medical Technology Design Class

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Abstract

This paper is a report on an interdisciplinary graduate/senior level medical technology design class offered through the electrical engineering department at California Polytechnic State University at San Luis Obispo Spring 2013. Participating students were from electrical engineering, biomedical engineering, computer engineering, psychology and computer science. The course had a major project component where student self-formed groups and did a project of interest to all members of the group. Grading of the project was based on a demonstration and report that were due at the end of the quarter. Due to the uniqueness of each project, weekly meetings were set up where the students reported progress and problems. An ongoing Google-Doc document was also created that they were required to update weekly and was graded. Lectures included topics which all majors could participate in such as privacy and security, ethics, discussions of computer systems where humans are considered an element and a more technical section where each major taught the rest of the class something that was related to the course that they were experts on. Grading was largely based on the project but also included class participation and class presentations. The course was well received by the majority of students and there was gratitude expressed from the students for the opportunity to work with students from other disciplines. Projects from the class spawned a product (already in use by CalTrans), multiple Master's projects, multiple senior projects, and a new collaboration between electrical engineering, materials science, biomedical department and a group on campus doing printed circuits in the Graphic Communication department. The course not only gave the students an opportunity to explore how to work with interdisciplinary teams but also a view into other specialties that they might need to seek out to complete projects in the future.

Introduction

Cal Poly implements its "learn by doing" tenet by pairing most lecture classes with a laboratory. Some labs allow the student to verify that a theory that was introduced during the lecture part of the class holds true and some labs are to allow the students to practice design techniques and give them the opportunity to make design decisions. But, due to the tight schedule of an electrical engineering (EE) and computer engineering (CPE) students at Cal Poly, the majority of their labs are limited to EE or CPE topics. Of course we want to make our students expert EE and CPE graduates so stressing EE and CPE topics in lab is a given but since I have arrived at Cal Poly, there has been a growing number of EE and CPE students coming to me and asking about doing medical technology projects. The interest in applying their EE/CPE knowledge to a problem from the medical technology field was of high interest to them (and me) and I looked for a way to provide an opportunity for them to put some time into exploring what their training can be used for in other fields Cal Poly has a biomedical club as well as a diabetes club and I had the opportunity to visit and listen to the students from these two groups discuss projects and interests. There was a common theme that the members of these groups were facing the same issues as the EEs and CPEs: They had knowledge of their specialties and had an interest in

building devices based on their knowledge but their EE/CPE knowledge wasn't in depth enough to actually bring their ideas to fruition. From there it was a small step to come up with the idea for an inter/multi- disciplinary course where the students could share their knowledge in order for both to build something that they couldn't (easily) build on their own.

The course I hijacked was a graduate level course called "Computer Systems". This may not seem an appropriate class to do interdisciplinary projects in but if you look at the newest definitions of a computer system, you'll see that, now, many places consider humans as a component of a computer system. I opened the course up to all majors and ended up with students from EE, CPE, CSC, Biomed and psychology in the class. The fact that it was a graduate class brought more mature students and students that had a clearer idea of what they wanted to do in the future. Due to the time they had already spent in project courses, many of them came with ideas and were truly interested in making their projects work. The interaction between students of different backgrounds all very invested in creating a functioning "product" was a very rewarding sight to see. This report describes the structure and "process" of the course and then gives a self-evaluation of what needs to be changed or improved.

Challenges

The course had a number of challenges including making it available to a population of students with pretty stringent course requirements and not much ability to select courses freely. The course counted for EE and CPE students as a technical elective but was not a credit course for the other majors. There was no way around this barrier except to hope that there were students that were interested in taking courses purely for the knowledge. The result was a body of students that were truly interested and driven to complete their projects. The students from other majors that took this class were outstanding and probably the reason for the success of this class.

There was a financial barrier to some of the projects that was covered partly by the students themselves, partly by me and, in some cases, by partial department support. We were supported by the department technicians and some projects used components from salvage or the back room of the hardware technician. The lab assigned to the class was a digital lab and some of the equipment required for testing of devices was not available in the assigned lab. Cal Poly has open electronics labs so the equipment barrier was overcome by giving the groups that needed access to particular equipment access to those labs. Labs used include the assigned digital lab, the basic electronics labs, the RF lab and a room for testing of the video signal processing project.

I envisioned a time issue. The course was just 10 weeks long and the first few weeks, I assumed, would be dedicated to finding an appropriate project. Thanks again to the quality and diligence of the students that signed up for this class, projects were already being built by the third week of class and all but one of the nine groups had a working prototype in week 10. The knowledge for each project was gathered by the students participating in each project. If I didn't have the information, I or the students would search for references or contact an expert to ask for help. Cal Poly has access to the IEEE journal database which was extremely helpful. I also greatly appreciated the support from professors at UCLA and UCI for their support to the eldercare daily diary health monitoring project and to the Cal Poly professors that gave support on the Glucose sensor project. There were 29 students in the class (plus 3 students just participating in the

projects). Mentoring that many students who are all doing different projects was a challenge and would have been a problem if the students themselves were not as self-starting and if I didn't have the help of professors around the campus and from other schools. Due to the limited number of upper level technical courses, the next time this course is taught, content will have to include the original advanced computer architecture content. I believe in this class project so I am planning on still offering the course to the non-EE/CPE/CSC students but then also have either one separate lecture per week where I split the EEs, CPEs and CSCs from the other students in the course for some number of weeks so I can talk about the required computer architecture topics to the EE, CPE and CSC majors.

Course Lecture and Lab Content

A general schedule of the course is included in Appendix A. Due to the variety of backgrounds in the class, lecture was a challenge. Successful portions of the course included discussions that each major could come at from their own viewpoint. For example, reading on electronic medical records was assigned in the first week. Each student had a role assigned to them and they were told that they would have to argue for their viewpoint in class on week 2. Roles assigned included a drug company representative, a patient going to the emergency room, an insurance company representative, a small practice manager, an HMO, a large hospital and others. The assignment showed the students that for the same information, various meanings can be taken. Subsequently a discussion of systems and designing for a range of users was discussed.

The course's technical content was split between the lab and the lecture but, since there was such a wide variation in knowledge of the students, lectures on technical topics were limited to topics that would be new to all students. The second half of the course had the students that were experts in a topic teach the class for part of a lecture. I believe having the students teach what they are experts in gives them a greater stake in the class, solidifies their knowledge and keeps them from getting bored, but this turned out to be the weakest portion of the class. Some presentations were done well but more than half spoke over the level of the students in the class, went too fast or targeted topics that may have been off the most important topics in the class. I will be teaching this course again Spring of 2014 and I will try this again but I will work with each group individually before they present to do quality control.

Discussions of the direction of healthcare and future healthcare systems were well received. Balancing monitoring and information gathering against security and privacy was augmented with a guest lecturer on an imaginary electronic medical record system. Again tradeoffs were discussed in class. Example systems were introduced and discussed. Looking at the direction of healthcare monitoring allowed the introduction of ethics related topics. Not only privacy and security issues but also issues surrounding legal issues around embedded electronics in humans and what are acceptable danger levels from devices like cell phones.

Techniques to Keep Students On-Track

The large number of students in the class and the variety of projects being carried out made it necessary to provide individual feedback to each group. The technique I tried in class was to have students post to Google-Docs or DropBox and then had them share the folder with me. The document would start out as an empty document with just the proposal at the head and then titles for the various sections that should be filled in as the quarter progressed. At a specified day and time the plan was for me to go into that document, make comments and suggestions on technical

points and on their progress. I felt this would be useful in keeping track of who was falling behind as well as give me time to research topic that I didn't know enough about to make a useful comment. Unfortunately technical difficulties kept this system from working (though it worked well in a subsequent design class) and I feel I let the students down in the area of support of their projects though the Google-doc. I plan on using this system when I teach the class again. This technique seemed to work well on getting the reports in on time in that each week they were just filling in empty spaces in what was originally their proposal. The documents were supposed to prepare me for weekly meetings with the groups. As mentioned, this didn't happen but the weekly meetings in lab did work and allowed me to redirect or correct groups if needed and to give me an idea of where the group was in terms of their schedule. The paper trail that a Google-doc would have provided would have been useful.

Assessment

This was a major problem for me and must be improved in future quarters. The course was to be assessed largely on the project but also on participation, presentations and report. The good news and the bad news is that all groups applied themselves seriously and produced outstanding products. Attendance was solid and presentations all good. I didn't have a midterm and had a very hard time separating one person's grade from another. At the beginning of the quarter I did not predict the quality and success of the projects done in the class. From the 9 projects, 5 or 6 papers will be going out to conferences such as EMBS (IEEE Engineering in Medicine and Biology) conference, IEEE Healthcare Innovation Point-of-care technologies conference, and others. This is inspiration to have the students write a conference-like paper in the class that can be sent in almost as-is to a conference later. Because of the quality of the projects, we had a mini-expo in the lobby of the electrical and computer engineering building that was open to students and faculty where the students presented their project through demos and posters. Again the challenge was that all students did an exemplary job and I had very little to separate the students grade-wise.

When I teach the course again, I plan on having more assignments including weekly short summaries of the reading and questions on the reading and class as homework. The course, as I ran it, had assignments every two weeks. That was not enough to separate grades or truly see if a student was keeping up with the material. The presentations were given a done/not done grade and that will be changed to a score in various aspects such as preparation/organization, completeness, presentation as well as scoring the audience for attendance on those days. The course does not lend itself well to a midterm but I hope an improved effort to check up on them weekly will improve the quality of assessment.

Project Groups

There was a total of nine projects attempted and those projects ranged from individual projects to two groups with six people. The division of labor was left to the groups but I required them to list up the task assignments for each individual in their initial proposal. Due to this class only being taken seniors and graduate students, the student had already had multiple years of experiences at picking project groups, planning projects and negotiating. The myriad of lab and project classes that Cal Poly students take seems to have prepared the groups well for not just the technical aspects of forming a successful group, but also the managerial aspects of forming a successful group. An example of a successful group is a group that wanted to investigate clear circuits and

how they could be used in medical technology. The group had six members and the tasks were divided up in the following way:

Group leader (EE): power transfer to contact lens / printing of circuits on lens
CPE: Application prototype to put onto lens (built successfully but not to scale)
Biomed: Materials appropriate for being printed on AND appropriate for use in an eye
EE1: Building of model eye to test contact lens.
EE2: Energy scavenging through light and energy storage.

This group printed out a prototype on a hard contact lens that received power wirelessly (in 7 weeks!). This project interested them enough that it is now the group leader's MS project. The group has applied for and received money for two grants and now has six members. A great contribution by the members of this group in fabrication of clear very small batteries that would fit on a contact lens. Tests are being done now and results should be available before Summer. The biomed major is following up on manufacturing. He is looking at materials and safety issues of circuits on the eye. This class was the catalyst needed to start a multi-disciplinary team that now involves four departments. Another project was done by a single biomed student that had had trouble getting information for his MS that was heavily EE. This class allowed him access to EE students and information that helped him in his biomed work. A group that did an impressive job of management did an EEG project that gathered EEG
data and then sent it to a cell phone where it was displayed.

Group leader (EE): Programmed an app for his phone that received data from his computer wirelessly and then graphed and displayed it.
Biomed: Used 3D printer to create a variety of shaped electrodes and tested them for their performance as dry electrodes.
EE: Built amplifier that goes on electrodes plus the processing hardware that creates the signal to be transmitted to the phone.
Psychology: Used a database of brainwave shapes to compare to gather brainwaves.

The challenge of doing such a project in just, effectively, 7 weeks, is that if there is an unexpected problem, the project can get completely off-track. The amplifiers bought for this project came from a faulty batch and caused this group to waste 2 weeks on talking with the company and fighting to get the devices to work. A new batch was provided free of charge by the company and those worked first time. But they had already lost 2 weeks and did not get to attempt the comparison to the database waveforms Other projects included a hand gesture wheelchair controller, sound altering headset for relaxation, glucose meter, eldercare diary system to detect long-term physical and mental health, a "fall" data gathering system, and heart rate monitor that uses changes in face color to determine heart rate. The last project used the fact that your face changes color imperceptibly every time your heart beats. These students took a non-real-time algorithm from a research group at MIT and made it real-time. Again, all of these groups found their projects, organized their groups, planned their schedule and carried out their own research.

Conclusion

An interdisciplinary medical technology class was offered Spring 2013 at Cal Poly, San Luis

Obispo under the electrical engineering department heading and officially called “Computer Systems”. It was open to any student with upper division or graduate standing. Projects were of their own choice as was the schedule and task assignment in carrying out those projects. The skills Cal Poly students learned through many labs they had to take before this class helped them make mature, quality decisions and the projects were largely successful. The labs were a success resulting in at least one patent application, multiple multi-disciplinary Masters and senior projects and the creation of a continuing joint research project involving materials, biomedical, electrical and graphics arts that has gotten attention nationally.

The lecture was difficult due to the mixed experiences and knowledge of the students taking the class. I presented the lectures for the first half of the class trying to build a big picture view of systems for healthcare and then, as we tried to go into more depth on some topics, I had the students that were experts in the topics teach the other students in the class to keep them participating in the course. This didn’t work as well as I would have liked and I will preview presentations if I do this again. Some presentations were done well but more than half spoke over the level of the students in the class, went too fast or targeted topics that may have been off the most important topics in the class.

Assessment was another challenge due to every student fully participating and succeeding in the class. More assignments needed to be assigned to see if students are keeping up weekly rather than every other week. Questions on the reading will also be given to further guide the students through the important points of the reading. The student evaluations were in general positive about the course though I think there were students that would have liked to have gotten more from the lectures.

Appendix A: General Course Schedule

Week 1

Lecture: Definition of computer systems with humans as a component, traditional and new medical technology introduction with a short introduction to technology that has made these systems possible. (To help with decisions on projects). Short introduction to reading: Electronic health records. Proper language when discussing people with challenges.

Assignment: Reading of papers on security, privacy, HIPAA (Health Insurance Portability and Accountability Act), and other legal and ethical issues surrounding having individuals as part of a system or having their data stored or available on a system. I assigned roles randomly to the students such as doctor at large hospital, doctor at small practice, patient at emergency room, insurer, drug sales person, identity thief, government, etc. and asked them to, as they read, try to find information that would support or not support a nation-wide (or world- wide) database of each of our health information for their interest.

Lab: Student introductions including department that they belong to and their research and/or project interests. Listing of problems that would be interesting or important to solve. Mingling between students to talk about interests.

Week 2

Lecture: A discussion with each student taking on their assigned role from the last week's reading and debating with the others why we should or shouldn't have a nation-wide (or world-wide) database of each of our health information. Continued: Traditional and new medical technology introduction with a short introduction to technology that has made these systems possible. (To help with decisions on projects). Future mental health technologies. User interfaces and dangers of various systems.

Assignment: Watching videos on: 1. safety of electronic devices, 2. creative health monitoring devices and 3. iPhone apps. Reading on security and ethics. Homework: Find one security breach that you thought was interesting and present to class. Reading on future HMI (human machine interfaces).

Lab: Group discussions of topics and interests. I participated in each group's discussion and tried to brainstorm with them.

Week 3

Lecture: Guest lecturer on security. Presentation on security breaches from each student. Continued: User interfaces and dangers of various systems. Costs of systems. Pervasive computing. High-level technology for pervasive computing.

Assignment: Reading of papers on: 1. pervasive computing, 2. birth of datifacation (fiction), 3. Company webpage for keep tweeting after you are dead.
Lab: Proposal due with schedule and deliverables specified. Work on project. Meeting with me.

Week 4

Lecture: AI and decision making. Presentations of project plans.

Assignment: Watch TED talk on prosthetics that can feel. Watch videos on Hanson Robotics (Especially TED talk and Philip K. Dick Android). Reading of papers on: 1. Pervasive computing, 2. birth of datifacation (fiction), 3. Company webpage for keep tweeting after you are dead. Discussion on-line on ethics and dangers of AI and decision making. Two entries required from each student.

Lab: Updated report due. Work on project. Meeting with me.

Week 5

Lecture: Guest lecturer on autism and autism devices. First (computer architecture introduction) and second expert presentation (programming a microcontroller). (Students present to other students on technical topics that not all students in class will know).
Assignment: Comments and questions on presentations. Time to be spent on project.

Lab: Updated report due. Work on project. Meeting with me.

Week 6

Lecture: Powering mobile systems. Third (How to make a processor faster) and fourth (BioMed or psych student presentation) expert presentation on topics assigned in class. (Students present

to other students on technical topics that not all students in class will know).

Assignment: Comments and questions on presentations. Time to be spent on project.

Lab: Updated report due. Work on project. Meeting with me.

Week 7
Lecture: Fifth (How memory works), sixth (BioMed or psych student presentation) and seventh (sensors) expert presentation on topics assigned in class. (Students present to other students on technical topics that not all students in class will know).

Assignment: Comments and questions on presentations. Presentation in lab of challenges faced in designing project. Design review.

Lab: Updated report due. Work on project. See "Assignments".

Week 8
Lecture: Design metrics, documentation of project and report format. Eighth (Communication – networks, protocols, wireless communication, etc.) and ninth (BioMed or psych student presentation) expert presentation on topics assigned in class. (Students present to other students on technical topics that not all students in class will know).

Assignment: Comments and questions on presentations. Time to be spent on project.

Lab: Updated report due. Work on project. Meeting with me.

Week 9
Lecture: Advanced computer system topics. Tenth (big data) and eleventh (BioMed or psych student presentation) expert presentation on topics assigned in class. (Students present to other students on technical topics that not all students in class will know).

Assignment: Comments and questions on presentations. Time to be spent on project.

Lab: Updated report due. Work on project. Meeting with me.

Week 10
Lecture: Picture of global pervasive computing and system requirements. Clouds and data that follows you as you move to different places on the earth.

Assignment: In class, student short presentation on what they realized this quarter about computer systems or medical technology that they didn't know before. Reports due. Demonstration at exhibition of class products in main electrical engineering building.

Lab: Demonstrations.