Teaching Seniors Through Developing Multidisciplinary Academies

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Most senior engineering majors perform a capstone design project. In some cases, this is a paper design and in some cases it is hands-on, but in most cases, it is with other engineers in the same discipline. For instance, at Tufts University, most mechanical engineers work with other mechanical engineers in their capstone design project. Because all team members have essentially the same content knowledge, it is often one or two students that do the bulk of the work. What if, instead, one of the team members was an electrical engineer? All of a sudden, the project can have some advanced electronics. Add a computer scientist and now there is a microprocessor controlling everything. Next, a human factors student designs the interface so that the user clearly understands how to use the invention. Finally, a child development major leads the group in an after-school program teaching the engineering concepts to elementary and middle school children. Now the Tufts students are learning from each other—the mechanics, electronics, interface, and better communication skills. This is the idea of the Tufts University Robotics Academy.

Learning is a social process that occurs between people who come together and share skill sets. Researchers believe there is an intimate connection between knowledge and activity (1). Hands-on learning and constructivism (2,3) are based on this idea and are common in elementary schools but are much more rare in college. With the academy, we are forming a community in which the students are enriched by participating in the shared goal of creating their project and sharing it with students. Each Robotics Academy member is slowly brought from being "the child development major" or "the electrical engineer" to being a full-fledged member of the team.

The Robotics Academy was started two years ago as part of an NSF CCLI grant, with professors from five different departments and two schools. So far, we have supported 20 seniors from all the majors mentioned above to develop robots to solve medical problems (a robotic endoscope), entertain (a kinetic sculpture), and for safety (a group of "smelling" robots that could identify a potential threat and go to it). This next year, students are working with the New England Medical Center to develop a robot that will help measure the amount of food eaten by fruit fly larva.

A Sample Robotics Problem

It is easiest to explain the idea behind the academy with a sample year. This year, students are working on developing a robotic system to measure the amount of food eaten by a fruit fly. The main idea is that one can map the genome of the fruit fly to the genome of the human, implying that one can look for genetic differences in the fruit flies and correlate that to human behavior. Obesity, in particular, is a rapidly growing problem in the U.S. (4), and if researchers can isolate the genes responsible for overeating, they will be able to help stop the spread of obesity. One way to isolate these genes is to examine the eating habits of fruit fly larva and correlate their consumption with their genetic makeup. Unfortunately, this requires graduate students to measure consumption on individual larva across up to 5,000 different genetic lines. Therefore, the team this year is looking at a way to develop a robot to make these measurements, so that the graduate student can measure 50–100 larvae at once.

Problems like this one have a number of advantages. First, the students are working on a highly relevant problem (obesity is predicted to soon become the number one killer in the U.S.). Second, they are using their skills in an area new to them, implying that they learn some biology along the way. Third, students take a problem from conception to a working product, giving them the skills to do something similar once they enter industry. Fourth, this problem will require skills in mechanics, electronics, computers, user interface, and education/communication. This means that each team member will be highly valued for his or her skill set and not feel redundant. They will learn from each other, learning how to learn on their own, with only some mentorship from the faculty.

The Academy Vision

Our eventual vision is to have a number of academies available to the junior. Each one has a different focus, allowing every student to follow his or her passion. To date, we have three of them in place: Musical Instrument Engineering, Robotics Academy, and a new one in medicine called Bringing Engineers into New Disciplines (BEND). The musical instruments program is the oldest and brings together musicians, engineers, and even economics majors. They build both conventional instruments (we have seen violins, lutes, bells, and even a new incarnation of a cello [Figure 1]) and new electronic instruments. The latter can be a set of gloves that allow you to play a sort of virtual piano, or a washboard that supplies musical instrument digital interface (MIDI) signals, or even a mechanism that turns your elbow into an instrument, with the elbow angle dictating the pitch of the note. The BEND program is a new collaboration starting between a number of departments and the medical school. There are a number of research programs that could really benefit from the participation of a few engineers. For instance, one researcher has been looking at the effect of exercise on bone growth, but needs a way to measure if the person is walking, jumping, running, or sitting. A few engineers could develop a sensor that is mounted in the sole of a shoe, for instance. This would allow the researcher to obtain complete histories of the motion of the foot.

Figure 1. A new incarnation of a cello.

There are a number of other possible academies that do not yet exist. Environmental engineering provides students with another socially relevant, exciting, and rewarding area of study. Artificial tissue design, brain monitoring, and chemistry labs on Mars are all programs that are currently happening at Tufts and would make very exciting multidisciplinary academies.

Student Response

So far, the student response has been overwhelmingly positive. At the beginning of the senior year, the students do not see the advantages of the other team members, nor do they have a good idea of how to work to a schedule, how to work with people of other disciplines, or even how to order parts, solder, weld, and teach. By the end of the year, at the completion of their senior thesis, their remarks are completely different. Many claim that this is the most influential class they have taken at Tufts. In fact, most students (80%) said that the program taught them the importance of planning and time management, whereas only 26% found that they improved their design and building skills. Many students (63%) found the greatest challenge was communicating with other team members and coordinating the responsibilities among the team, but only 16% found it challenging to combine different ideas into a coherent action plan. Many (63%) of the students thought the main advantage of working in multidisciplinary groups was the exposure to different perspectives and learning styles as well as learning about other majors.

Faculty Response

The faculty members involved are all quite enthusiastic about the program. Members of the engineering school created the Robotics Academy because they "wanted a cool way to get engineers in education and education students interested in engineering." Although the participating faculty members were excited about the program, many thought it was overly ambitious and were skeptical at first. All faculty and staff members expected the Robotics Academy to be an interdisciplinary program, which would be run by a group of students with a variety of perspectives. This would allow students to develop strong organization skills and fluent communication among students and between students and faculty. Despite initial doubts, all of the faculty and staff members felt the program successfully met all of their expectations. One faculty member commented that the Robotics Academy "went above and beyond his wildest dreams."

Issues and Lessons Learned

The academy model brings with it some inherent difficulties that are not found in the conventional classroom. Students work on their own schedule and set their own deadlines. Faculty mentors have very little control and therefore much less responsibility. It is difficult to provide enough of a structure that the students actually accomplish their goals, while keeping the leadership in the hands of the students and not the faculty. We believe that it is essential to have students control the direction of the project during the academy. The instant the faculty members take control, the whole program changes and the student engagement decreases. We require the students to present four progress report presentations over the course of the year. We also have a teaching assistant who meets with the students weekly and helps lead the program. This TA changes every year, allowing for new ideas while still having some overlap, because the previous year's TA is still finishing up his or her master's research. Undergraduates seem to feel more at ease with talking to a graduate student before going to one of the faculty mentors.

Probably the greatest single difficulty in these academies is grading. Because all work is group-driven and done outside the scope of a normal classroom or laboratory session, it is difficult for the faculty member to really know the extent of the effort and work put in by any one student. For this reason, we have developed a number of grading schemes. First, we give all students a grading metric at the beginning of the year so that they know how they will be graded. Second, each department mentor is ultimately responsible for the grades of the students in that department. Third, students are issued an individual grade (based on the metric, with input from the TA and all of the faculty mentors), and then their honors theses are rated. Students with theses written obviously in the last week will receive only a "thesis" designation. Those who have a well-written, coherent thesis that might some day be worked into a publication get "honors"; those who write a thesis that is ready for publication get "high honors"; and once every few years, someone who has obviously gone well beyond all expectation will receive "highest honors."

The last issue is that of content knowledge. The engineering knowledge of an average child development major and the teaching knowledge of the average engineer is poor. It usually takes a semester (at least) to get the two groups working comfortably together. Because of this, we are now starting a course that is co-taught between engineering and child development. This will be our first attempt at multidisciplinary courses, where students from both departments will be working together on homework assignments as well as class projects. With this, we hope to get more education content in the engineering curriculum and more engineering content in the education curriculum. This course will be run for the first time in the spring of 2005.

Conclusion

We have found that giving students the opportunity to work on problems in an area of personal interest, with team members from a number of different disciplines, has resulted in students learning how to learn from each other, how to work effectively as a team, and how to meet deadlines and estimate budgets. The student response to this experience has been far better than expected. Some students have chosen to continue onto graduate school, other students have started careers related to their experiences in the academy, and many have commented that this experience was helpful during their job interviews, as well as in adjusting to working in multidisciplinary teams on the job. Students who had a skeptical attitude about the academy at the beginning of the year graduated saying that the experience was the best thing they did in their four years at Tufts. Students who were scared and nervous about running an after-school program were sad to see the children leave at the end of the program. The most impressive part, however, was to hear what the students had to say about the experience and what they had learned. They went from sounding like students to sounding like our alumni in industry, talking about the need for better team communication, more socially relevant work, and more freedom to choose the project direction.

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