Abstract - While many have explored multidisciplinary approaches to course content delivery in computer science and engineering, very few have combined engineering with fundamentally different disciplines such as the arts, humanities, or social science. This paper presents a multidisciplinary undergraduate seminar entitled “Conducting Robots” that brings together majors from four disparate disciplines: computer science, mechanical engineering, music, and interactive multimedia. The goal of the course is to teach and support interdisciplinary teamwork while student teams build an artificial system that can conduct the college orchestra. The end-of-semester survey shows that students found the course interesting and challenging, motivating them to collaborate with peers across disciplines.

Index Terms – computer science, robotics, orchestral conducting, course assessment.

INTRODUCTION

Science and technology have an image problem: scientists and engineers are commonly perceived as “nerds” who spend their lives doing things that nobody else understands. When asked to list creative activities, people will rarely mention science or engineering, offering arts and humanities areas instead. Many undergraduate students complain that science and engineering subjects are difficult and boring. It can sometimes take years of study before they realize that these can actually be creative domains. Not only can one work creatively within them, but they can also be applied to other fields in service of a creative goal [1].

With this situation in mind, we designed and taught a multidisciplinary undergraduate seminar with the goal to engage students – majors and non-majors alike – creatively in science and technology. Specifically, we applied the fields of computer science and mechanical engineering to a field that has traditionally been seen as more creative: music.

Many of the most pressing problems of the day are best solved using multidisciplinary approaches [2]. However, the standard paradigm in multidisciplinary work is that it requires participants to become fluent in all of the participating disciplines, sometimes sacrificing depth for the sake of breadth. Our approach, similarly to other multidisciplinary approaches [3] modifies this scenario through the participation of specialists from different fields who have the necessary skills to communicate with each other and produce a collaborative solution through a common perspective. These specialists seek to avoid and overcome the convenient, subjective stereotyped, disciplinary labels. Instead, they aim to be modern, educated, multi-dimensional individuals who can reach across disciplines and innovate in both the arts and sciences. Undergraduate institutions should prepare our students for future opportunities by teaching them to reach across the boundaries of their own disciplines and find creative solutions to difficult problems.

Regardless of their subject discipline, 21st-century undergraduates will be better served by a multidisciplinary approach to education, to prepare them for future tasks and environments. Non-computer science majors should become familiar with concepts of computational thinking, while computer science majors should learn to communicate with specialists from other disciplines.

Recently, a wide variety of interdisciplinary approaches to computer science education have been developed and described in the literature, ranging from entire programs [4] to interdisciplinary courses that combine computer science with computer games [5], robotics [6], science [7, 3], media [4], and music [8]. On the engineering side, although a variety of interdisciplinary courses have been developed, [9, 10, 11], there still remains a lack of courses that involve disciplines that are fundamentally different from engineering such as arts, humanities, and social science.

In this paper we describe a multidisciplinary approach to teaching computer science and mechanical engineering through an undergraduate seminar entitled "Conducting Robots." Our course brings together students majoring in computer science, mechanical engineering, interactive multimedia and music in a common setting. It is a project-oriented course that fosters critical thinking, creative problem solving, and computational thinking skills through an open-ended team project. The end-of-semester survey shows that students found the course interesting and challenging, motivating them to collaborate with peers across disciplines. In addition, our assessments show that students improved their knowledge in all four disciplines represented in the course.
COURSE STRUCTURE

In the multidisciplinary undergraduate seminar that we developed, student teams built non-human systems that conducted our college orchestra. Called “Conducting Robots,” this semester-long course has been offered four times so far. Each semester the course was cross-listed in the departments of Computer Science, Interactive Multimedia, Mechanical Engineering, and Music, and was taught by a team of four instructors, one from each department (the authors). We worked with an independent evaluator to develop and administer student surveys and interviews. In addition, students were asked to keep a reflection journal. These tools were used to evaluate and modify the course based on student feedback, as well as to assess student creativity and document the creative process.

Since it is a multidisciplinary seminar open to students with different backgrounds, the structure of the Conducting Robots course is different from that of a traditional course. Students form interdisciplinary teams during the first few weeks and start brainstorming design ideas right away. The semester starts with one or two lectures in each discipline, which serve as a refresher to in-major students while providing out-of-major students with a basic introduction. Topics include robotics, visual music, abstract animation, algorithms, data processing, procedural animation, music conducting, and project management. Homeworks are assigned in each discipline, and students are expected to rely on their in-major teammates for problem solving. After this introductory period, teams spend their time designing and building their systems. The class structure changes from the traditional lecture to a less formal conversational setting, where teams share progress reports and discuss specific project-related problems with the instructors. Depending on the situation, instructors invite guest speakers to better address the issues encountered by the teams.

The final objective of the course is to have students build graphical and/or robotic non-human conductors that can conduct an orchestra. The minimum requirement for each system is to indicate beat patterns, tempo, dynamics and cueing to a human ensemble in real-time. Throughout the course, students work together in multidisciplinary teams, contributing and developing knowledge from within their own fields, as well as learning fundamentals from the other fields involved.

Since many of the students were not very familiar with classical music, numerous opportunities were provided to give them exposure. In addition to the regular weekly class meetings, students were required to attend and review one rehearsal session of the college orchestra. The instructors arranged for group trips to see concerts by professional orchestras. Additionally, the conductor of the college orchestra served as a consultant on this project, and made himself personally available to the students for interviews and discussions about conducting technique.

We initially envisioned an ideal enrollment of 20 to 24 students and would ensure that each major is represented on each team. Unfortunately, the number of students varied significantly each semester, often because of scheduling issues (our students came from four different majors, housed in three different schools with different requirements and expectations). Table I shows the number of students from each major enrolled in each of the four semesters the course was offered.

<table>
<thead>
<tr>
<th>Semester</th>
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<th>Engineering</th>
<th>IMM</th>
<th>Music</th>
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The biggest enrollment challenge was to ensure an adequate number of engineering majors. Teams without engineering majors were not required to build a physical robot; they created an animation. The number of music majors also varied widely. In the semester with one music major, all teams worked on the same music pieces and tried to share as much musical knowledge as possible.

PROTOTYPES DELIVERED

Throughout the course, students worked together in multidisciplinary teams, contributing and developing knowledge from within their own fields, as well as learning fundamentals from the other fields involved. At the end of each semester, each team successfully demonstrated a functional system that performed in a live presentation with student musicians. Each system fit one of four categories: humanoid robots (e.g., Honda’s ASIMO, whose conducting performance [12] inspired some of the students), humanoid animations, non-humanoid robots (including devices tailored for individual musicians), and non-humanoid animations (some akin to video game interfaces). Some of the prototypes are pictured in Figure 1.

![Figure 1](image)
The course presented a number of challenges for students and faculty alike, but all students built working conducting systems at a level that is rare in an undergraduate setting, and is more characteristic of graduate research. While doing so, they learned to collaborate with other students and apply their knowledge to other fields, as well as to communicate cogently about their own disciplines to non-specialists.

**COURSE OUTCOMES**

Building conducting robots was the underlying pretext for our course. While we were delighted to see students successfully construct functional non-human conductors, robots and animations alike, our real goal was to bring together students from a variety of disciplines to teach them creative problem solving. Our hope was that, through this experience, students would learn how to use their knowledge in their own discipline to interact with individuals from other disciplines. It was our goal that students would expand their own disciplinary knowledge as well as in the other fields involved in the project, and would ultimately become more confident of their capacity for creativity.

To measure our success, at the end of each semester we conducted a general survey related to the goals and objectives of this course. Students were asked if they thought they improved their knowledge, problem solving ability, creativity, and confidence, whether they found the course interesting and challenging, and how much they contributed to the project. Answers were given on a scale of 1 to 10 where 1 stood for “not much at all” and 10 was “an extraordinary amount”. The average rating for all the questions ranged between 4.8 and 8.1, with most above 6. The detailed survey questions and results are listed below.

- **How much did you expand your horizons with respect to the amount you know about the other three disciplines? Which other discipline did you learn the most about?**
  All students reported that they learned about the other disciplines, with an average rating of 6.3 and a median of 7. They reported learning the most about music and mechanical engineering.

- **How much did you expand your horizons with respect to the amount you know about your own discipline?**
  Students reported learning less about their own discipline, with an average rating of 5.3, and a median of 5.

- **How interesting did you find this course?**
  Students reported finding the course very interesting, with an average rating of 8.1 and a median of 8.

- **How challenging did you find this course?**
  Students found the course moderately challenging with an average rating of 7.4 and a median of 6.

- **How helpful was the cross-disciplinary environment for the problem solving needed for needed for completing assignments?**
  Students found the cross-disciplinary environment very helpful in completing homework and developing the project, with an average rating of 6.5 and a median of 8.

- **How much did the cross-disciplinary team environment increase the creativity of your solution?**
  Students reported finding the cross-disciplinary environment quite helpful for increasing the creativity of their project solutions. The average rating was 7.4, with a median of 7.

- **How much confidence did you gain in your own discipline as you explained it to your team members?**
  Students reported moderate gains in confidence within their own discipline, with an average rating of 6.1 and a median of 7.

- **How much were you able to make a contribution to the project in a discipline outside your own?**
  Students reported making only moderate contributions in disciplines outside their own, with an average and a median of 6.

- **How much impact has participating in this course had on what you plan to do after you graduate?**
  Students reported that the course had a moderate impact on their plans after graduation, with a 4.8 average and a 5.5 median.

- **Would you recommend this course to others?**
  Students were enthusiastic about recommending the course to others, with an average rating of 7.7 and a median of 9.

Overall, students found the course interesting and challenging, and thought they improved their knowledge in all subjects involved, and especially in those that were not their own. To better assess the improvement of student knowledge, we administered tests at the beginning and end of each semester, consisting of questions from each subject area covered by the course. Table 2 shows the average improvement in the percentages scored by students at the beginning and the end of the semester by subject area each time the course was taught.

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<thead>
<tr>
<th>Semester</th>
<th>CS</th>
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<th>Music</th>
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Results vary from semester to semester, as the course was a work in progress, and some of its details were adjusted according to student performance and feedback. The largest variation was in the music knowledge acquired by course participants. Interestingly, but perhaps not so surprisingly, the semester with highest score improvement was the semester during which only one music major signed up for the class. In contrast, the semester with the lowest improvement was when most teams had two music majors. When the number of music majors was low, students from other majors had to study more about the field to ensure the successful completion of their project. Disciplinary problems were easier to solve when more majors were available.
Another goal of the course was to enhance student creativity by having them participate in a creative project. Results of our creativity assessment can be found in [13].

CONCLUSION
We presented an experiment in STEAM: merging science, technology and the arts through a multidisciplinary undergraduate seminar entitled “Conducting Robots.” Through this seminar, majors from four disciplines (computer science, mechanical engineering, interactive multimedia, and music) worked together, contributing their own expertise to multidisciplinary teams engaged in a common goal: building a non-human system that could conduct the college orchestra.

Throughout every semester that the course was offered, we used a hands-on approach with a limited number of traditional lectures. We tried to keep in-class discussions general, and allowed students to discover and teach each other the details. Due to the multidisciplinary collaboration our students were able to build working systems at a level that is rare in an undergraduate setting, and is more characteristic of graduate research.

Results of a general survey administered to course participants at the end of each offering indicate that students found the course interesting and challenging. It motivated students to share their knowledge and reach across the boundaries of their own disciplines. The interdisciplinary approach fostered creative problem solving through the participation of specialists from different fields who have the necessary skills to communicate with each other and produce collaborative and creative solutions through a common perspective. Students enjoyed the experience and were ready to recommend the course to their peers. Tests administered to students in each subject area covered by the course at the beginning and end of each semester show that students improved their knowledge in all subjects.

Our experience can be adapted to other multidisciplinary environments, combining attractive challenges with teams of diverse backgrounds.

REFERENCES

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