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Design Course for First-Year Students in Multiple Engineering Disciplines

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Dr. Oyanader earned his B.S. in Civil and Chemical Engineering from Northern Catholic University in Antofagasta-Chile in 1989; his M.S. in Information Systems from Hawaii Pacific University in 1994; and his Ph.D. in Environmental Engineering from Florida State University in 2004.

Dr. Oyanader joined the College of Engineering at California Baptist University in the fall of 2014 where he is currently an Associate Professor of Chemical Engineering. In the three years prior, he was an Associate Professor of the Department of Engineering and Computer Science at Geneva College in Beaver Falls, PA. From 2007 to 2011, he performed as the Unit Operation Lab Director and Chemical Engineering Program Coordinator at Tennessee Technological University in Cookeville, TN. Between 1996 and 2007, and Dr. Oyanader transitioned from Assistant Professor to Associate Professor of Chemical Engineering at Northern Catholic University in Antofagasta-Chile. He was Department Head for the Chemical Engineering Department at Northern Catholic University from 1998 to 2000. Within the chemical engineering discipline, Dr. Oyanader has taught several topics including Fluid Mechanics, Transport Phenomena, Thermodynamics, Unit Operations, Chemical Process Design, Process Simulation & Control, and Design of Experiment. His teaching of these subjects has been driven by the use of methodologies such as Active learning with Student Response Systems, Key Competencies Teaching, and One-On-One and Peer Training.

Dr. Oyanader has three main research interest focus areas: a) Applied Environmental Engineering, b) Electro-Bio-molecular Treatment and Separation, and c) Computational and Modeling Approach in Physicochemical Processes. His approach is based on the use of fundamental principles to explore solutions to a wide range of practical problems that includes effluent treatment, water decontamination, desalinization, drug delivery and the design of medical devices.

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Introduction

To address the retention issue in engineering education for multiple discipline, many universities are developing programs or curriculum to encourage students to continue to pursue the engineering discipline and help get over the first overwhelming perception and anxiety the student may encounter[1]. As one example, many engineering colleges around the nation introduce students to fundamental concepts of engineering through a first-year design course. Studies on the use of first-year design course have been conducted at Penn State, Cal Poly Pomona, and University of Colorado Boulder in order to observe their effect on students' understanding of fundamentals engineering disciplines, as well as their perceptions of engineering design and group work. These studies have not only shown an increase in the intellectual development of students, but showed improvements in problem-solving, collaborative work, and creativity[2,3]. Additionally, project-based learning has been shown to drastically increase retention rates, especially for women and minorities in engineering disciplines, while also increasing the long term retention of engineering material[4,5,6].

One challenge of first year engineering design courses is effectively exposing students, many of whom have not yet decided on a preferred engineering major to pursue, to the different engineering disciplines offered at their institution. This is done in order to make them more interested and confident in pursuing an engineering degree and allow them to make a more informed decision when declaring their major. In order to overcome this challenge, schools typically include professors from different departments to teach first year design courses. This in turn puts stress on the project as it must be teachable by professors from all departments and expose students to all engineering disciplines[7,8,9,10].

Not only should the course be interdisciplinary, use projects, and be teachable by professors from varying backgrounds, but a freshman design course should also teach design rather than just being a project course. This is important as it establishes design as a rigorous process and lays the foundation for future design courses. Teaching design in these courses must include teaching a design structure that is applicable for all disciplines that includes both engineering rigor and the importance of a design loop.

Background

California Baptist University (CBU) is a mid-sized, Christian, liberal arts university in Riverside, California. CBU Gordon and Jill Bourns College of Engineering has approximately 550 students with approximately 160 first year students. The college offers 10 different majors: biomedical engineering, chemical engineering, civil engineering, computer science, construction management, electrical & computer engineering, engineering, industrial and systems engineering, mechanical engineering, and software engineering. All of these degrees take the same EGR 102 Introduction to Engineering Design course in the second semester of their first year.

The project portion of EGR 102 consists of fourteen sections of approximately twelve students each. Each week two sections (approximately 24 students) meet together for a 90 minute project lecture to learn the design process and work on the project. Each section also meets individually during the week for a 90 minute lab session where they learn basic engineering principles and work on the project. Professors typically teach two sections of the course with the lead professor teaching four sections. One teacher's assistant helps with grading as well as holding additional evening office hours for the students.

The project for the course is based around a single elimination competition at the end of the semester where each lab section (twelve students) forms a team. The team's goal during the semester is to design a set of units (or machines) that will take objects(Acquisition Unit, Transportation Unit), shown in Figure 1, from the center of the arena to the team's designated end and sort(Sorting Unit) the objects into their eight different types. During the competition at the end of the semester another team will attempt to do this simultaneously and the teams are allowed to have a limited amount of interaction to deter the opposing team. Also during the competition, each team is scored on a combination of the recovery (based on the quantity of each object sorted correctly) and the purity (based on the sorting accuracy of each object). The team with the highest score is declared the winner.

Figure 1: Objects used in the competition

Each team is divided into three units in order to complete the task with approximately four students per unit. The acquisition unit will design a machine that stays in the middle of the arena and picks up the items from the middle. The transportation unit will design a machine that drives around the arena moving the objects and interfering with the opposing team. The sorting unit will design a machine that sorts the objects into the correct bin for scoring.

The design process is taught in three main ways: 1) brainstorming top-down designs 2) deterministic design, and 3) bottom-up prototyping. The first two processes are taken from Dr. A. Slocum's FUNdaMENTALS of Design course information from MIT's OpenCourseWare. The prototyping is done after brainstorming and involves going through at least four design loops.

The brainstorming process starts with students brainstorming on strategies for winning the competition. Students then brainstorm on strategies for each unit to execute the overall strategy. Next, students brainstorm on different machines that can execute each of those strategies. Finally, the machine is divided into different modules (functions) and students brainstorm on how each module could be executed. These steps are done by all students before they are assigned to the unit that they will be constructing for the project. Students come up with their ideas outside of class and then present them to their team during class for discussion and further brainstorming.

As the students are exposed to each level of the design process they are introduced to what we call ‘missional examples’ which require students to think of design requirements or engineering solutions for real world global issues. The college also requires student to complete service hours during their first year in the engineering program. These two things help the students to understand their purpose within their discipline which is the topmost priority of CBU and also enhances the experience of freshman design[11].

While the students are brainstorming, they are also required to do deterministic designs. Deterministic design breaks the design down into its different functions and states how they would agree with a client if their project is successfully completed or not, what calculations are necessary to ensure their design will meet that requirement, what risks there are in the design, and what countermeasures can be used to mitigate that risk. The basic design calculations such as gear ratios, how long actions will take, and the repose angle are aided by basic labs that take place over the first month of the course to aid students in these calculations.

The third method of design is iterative design/bottom-up prototyping. Each unit first construct their ideas out of cardboard and Lego pieces to present to the rest of the team for a design review. Next, students go through two rounds of prototyping with Legos, 3D-printed parts, and laser cut foam. During the first prototyping phase with foam, students build individual modules of their project and test them before assembling the entire machine. This allows them to test earlier and make changes when necessary. Finally, students make their revised designs with Legos, 3D-printed parts, and laser cut acrylic. Going through four rounds of prototyping allows students to realize the mistakes in their designs and change them multiple times throughout the project.

One goal of the course is to expose the students to the different engineering disciplines. This is done in two different ways. The first is by incorporating different aspects of the disciplines into the project itself as shown in Table 1. Secondly, a professor from each discipline is asked to make a video that is approximately five minutes long explaining which parts of the project best align with their discipline. Students are required to watch those videos and complete a quiz on each one. These videos are assigned after students have already selected the unit that they would like to work on to encourage students to do what they are naturally drawn towards rather than what discipline they think that they should pursue.

Table 1: Each engineering discipline is incorporated using various aspects of the project.

Engineering Discipline	**Project Elements Supporting that Degree**
Biomedical Engineering	EMG muscle activation of Mindstorms motors
Chemical Engineering	sorting of objects by their attributes
Civil Engineering	building structures
Computer Science	programming Lego Mindstorms controllers
Construction Management	project management

Electrical and Computer Engineering	sensors, motors, and controls
Industrial and Systems Engineering	engineering economics / cost analysis
Mechanical Engineering	gears, linkages, and motors
Software Engineering	programming Lego Mindstorms controllers

Methods

The course was assessed using a Likert scale survey that was approved by the IRB(Institutional Review Board). Students in sophomore level courses were asked during their class to volunteer to take the survey. Students were asked how well the project helped them "understand the following or importance of the following" and listed all of the degrees offered by the college of engineering. The same survey also asked for feedback on the design process that was taught by asking about "Designing on Multiple Levels (Strategy, Concept, Module)" and about "The designing, testing, and redesigning loop." The survey was administered approximately 4 months after the completion of the course and 64 students completed the survey.

Results and Discussion

The results showing student's perception of how well the different types of engineering were taught are shown in Figure 2 below. The different answers are shown by the stacked columns and the bars show the Likert number result. With the exception of biomedical engineering and chemical engineering, the majority of students thought that the degrees were covered. mechanical engineering was perceived to be the best covered. This is likely due to the amount of building and moving parts that were used in the project.

With respect to chemical engineering, which has within its discipline separation processes, i.e. distillation, solvent extraction, desalinization, screening etc., all of which involve a process that converts a single stream into at least one or two selectively richer in the original constituents. The sorting unit concept does exactly that. It converts an incoming stream containing all sizes and shapes of an object into one or more out streams containing an enriched amount of shapes or sizes. The nature of the sorting machine (units) the students design, develop and implement are close to real systems such as in screening and filtration operations in chemical engineering. So the low score for chemical engineering is surprising as the sorting aspect of the project was taken from a chemical engineering project from Ohio University[12].
This taught us that the actual project may not be enough to teach students about different engineering disciplines. If students do not understand a particular discipline, they will not be able to identify aspects of the project that relate to that discipline themselves.

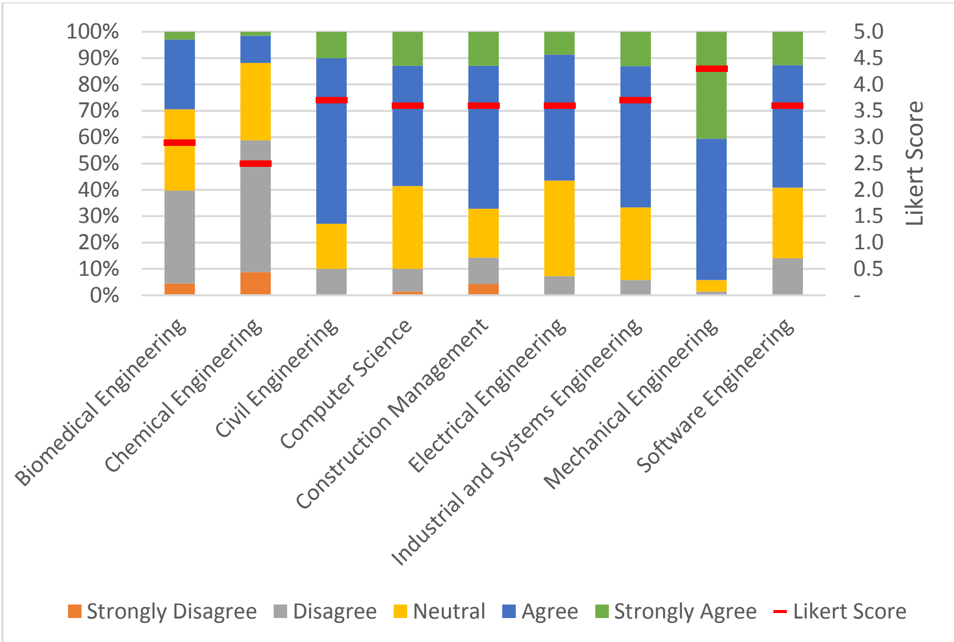

Figure 2: Student's perception of how the project helped them understand the different engineering disciplines.

Biomedical engineering and chemical engineering were found to be the most challenging to incorporate into a freshman design course. Design in biomedical engineering often includes interaction with the human body which is difficult to incorporate into a design project especially at the first year level. We attempted to do this through the use of using EMG to control a motor, however while all students were introduced to the process, only one out of the three units used the EMG controller. This may have resulted in students either not remembering the EMG input or not believing that it was a good enough representation of biomedical engineering.

Incorporating chemical engineering is also difficult as the design course is not suited to incorporate chemical reactions. The space where the course is taught is not a chemical-friendly environment, as it does not include chemical-resistant lab benches, chemical storage spaces, fume hoods, and sinks, and students at this stage have not necessarily taken chemistry and thus have not gained much experience in working with chemicals in terms of safety precautions. Additionally, the use of chemicals brings the risk of accidental chemical spills, which could lead to damaging other parts of the design project. Further work will be conducted in order to integrate more from chemical engineering.

Students indicated that they understood both Design on Multiple Levels (4.2) and Design Iterations (4.2) as shown in Figure 3. Only 3% of students indicated that they disagreed that they understood the importance of designing on multiple and only 4% disagreed that they understood the importance of design iteration. This was encouraging because it is applicable to design in all disciplines. Even if students do not feel that they learned about a specific engineering discipline, this course would still help them no matter which discipline they decide to pursue.

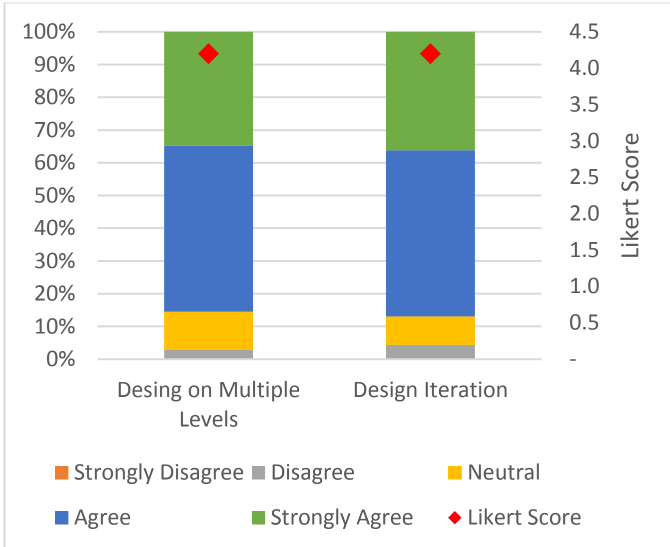

Figure 3: Student's perception of how the project taught them Design on Multiple Levels and Design Iteration.

The videos and quizzes that were used were given to the students in the last month of the course. At this time, students had already registered for their courses for the following spring and they were working hard to finish their projects on time. Starting the videos earlier in the semester and spreading them out more may help students focus more on different aspects of engineering. Also, this survey was administered 4 months after the completion of the course. This leaves the possibility that students forgot some of the information that they had learned about the different majors.

Conclusions

It is possible to teach a design course for first year engineering students that incorporates many different engineering disciplines while still teaching a design structure and iterative design. While some engineering disciplines were more difficult to include, we believe that better communication of how the project incorporates those disciplines would aid in students' understanding of those disciplines.

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