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A Multi-disciplinary Approach to Developing an Introductory Course in Engineering and Architecture

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Abstract – Engineering and architecture is aimed at improving the life of humans by designing and building products and services to the needs of civilizations. In real life settings, designing and building a product/service is a multidisciplinary event that involves the collaboration of a variety of specialists from different backgrounds. Accordingly, students need to acquire multidisciplinary skills and a holistic view of the world to be more successful in their future jobs. A committee of faculty from various disciplines in engineering and architecture at the American University of Beirut (AUB) was entrusted to design and introduce a new course that inspires creativity in engineering and design, engages first-year students from architecture and various engineering disciplines, and above all provides a multi-disciplinary experience to engineering education. This paper presents the theory, pedagogy, and background of introducing such a course to engineering and architecture students at AUB.

Keywords – Multi-disciplinary education, introduction to engineering and architecture, innovation in education, pedagogy.

1. Introduction

While education continues to advance towards more focus on specialized disciplines, the job market seems to be advancing at a faster pace towards multi-disciplinarily skills, with a much higher demand for well-rounded engineers and architects. Generally speaking, students often graduate in Engineering or Architecture without holistically understanding the different engineering perspectives and disciplines that enter into the whole engineering and design process. Students from the different departments of Engineering (e.g. Civil, Mechanical, Electrical, Computer, Industrial, Chemical, etc.) are often educated in silos with little exposure to the other disciplines. Architecture students, although commonly educated about the role of engineering disciplines within the building industry, are often not exposed to working jointly with engineers, and tend to design and develop their ideas in a detached manner. This lack of exposure, in turn, leads to lack of influence, and hence reduces the possibility for crossings of minds and disciplines, necessary often for innovation. This also leads to misconstruing possible

constraints during the early stages of the design process. Furthermore, students sometimes face difficulties after graduation, when they find themselves in work environments that require them to work in teams from multiple disciplines.

On another note, students often enter university, without being fully aware of their program's constituents, and without having sufficient information to make an educated choice. This is particularly true for students entering the Faculty of Engineering and Architecture (FEA) at the American University of Beirut (AUB) where students are not always clear about the distinction or overlaps between the different disciplines.

For these different reasons, an idea for cross-education in early years across FEA is proposed to expose students to the different disciplines and encourage collaboration, innovation, teamwork, and well-rounded knowledge. The goal is to have a common course that can introduce and educate new students to the different disciplines in engineering and architecture, in their first year. An additional motivation for the introductory nature of this education is that it could help students make a more educated choice of the program or field that they want to continue in. This objective presents several challenges. First, the instructor of such a course needs to be skilled in the different disciplines to provide the necessary multi-disciplinary information with sufficient depth. Second, the course content needs to have the right balance of being challenging, educational, and fun. The students need to be educated, yet at the same time enjoy the course and its varied content. Another challenge, of course, would be to bring together a large number of students from the different programs, in one course that needs to address and tailor for their different fields.

In this paper, we present this new introductory course targeted at first year students entering the programs of Engineering and Architecture. The course is taught by a committee of professors from the different programs, providing in-depth information about every discipline and exposing the students to multi-disciplinary interactions. The course is divided into program modules to enable flexibility in teaching of each field. However, multi-disciplinary aspects are emphasized within each discipline's module, and a common theme is used to illustrate the potential overlaps. Example themes include discussions about different aspects of a product, like a car or laptop, from design and architecture to consideration for different elements and components in industrial, chemical, electrical, mechanical, and civil engineering.

The rest of the paper is organized as follows. Section 2 presents related work in providing introductory engineering education to first year students. Section 3 provides a detailed description of the targeted course. Section 4 provides a conclusion and future directions.

2. Research Background

Several engineering schools have introduced a common undergraduate course for first year engineering students. The American University of Sharjah, UAE introduced a 2-credit hour required course for all students enrolled in the College of Engineering for six departments (Computer Science, Civil, Chemical, Computer, Electrical, and Mechanical Engineering). The goal of this course is to develop an understanding of the major responsibilities of engineers, foster collaboration among engineering disciplines, form a basic background in problem solving, as well as develop ethical responsibilities in

students. The course includes recitation lectures, six laboratory experiments each pertaining to one engineering discipline and a common design project such as paper bridges, Q-tip bridges, and paper airplanes. The results show, using both direct and indirect evaluations, that this course benefited students, met its objectives and also met ABET criteria. Furthermore, it was established that it is possible to provide a meaningful and well-rounded design experience to undergraduate engineering students with minimal conceptual foundation in their own engineering disciplines [2].

In response to the demand for enhanced design, problem-solving, and team skills in engineering graduates, Pennsylvania State University has instituted a course for first year engineering students to meet these fundamental aspects of the professions. Researchers found that this is important because recent studies show that engineering students are entering the workforce ill-prepared to solve real problems in a cooperative way, lacking the skills and motivation to continue learning. The course introduces students to design process skills in addition to traditional engineering content. It also emphasizes the importance of graphical, oral, and written communication and incorporates skill-oriented tasks, such as analysis, and interpretation of experimental data into team-oriented design projects. During the course, students spend less time in lectures and more time working on various hands-on design projects in teams. This allows them to discover that they cannot engage in open-ended, team-based, design projects without seeing that multiple solutions are possible, and that part of their task is to evaluate the many potential solutions on criteria that they must define. The analysis also suggests that having a multidisciplinary course may provide the type of intellectual environment that stimulates students' natural progression toward more complex thinking [3].

The Ohio State University provides its engineering students with a two course sequence during their first year of engineering that involve skill development applicable to all engineering disciplines. In these courses, students are required to design and build a scaled version of a roller coaster. This project engages them in a working knowledge of physics and engineering and exposes them to the various disciplines of engineering. The analysis of this course has shown that it provides students since their first year with crucial experience in time management, task scheduling, development of design techniques and problem solving skills. Finally, it also exposes them to the constraints of "real world" work and forces them to communicate and work in a collaborative environment [4].

Virginia Tech University offers a course required for engineering and design students with the target of showing students a glimpse of the real world and giving them a taste of collaboration between engineers and designers on interdisciplinary design projects. Throughout the years, the course contained different projects such as the design of push-pull toys, LEGO programmable RCX bricks, and a walking device using a rechargeable electric screwdriver as the power source. The responses towards this course indicated an increased understanding and students' appreciation for their own discipline as well as the other disciplines. Working in interdisciplinary groups fostered communication and allowed students to realize that "there is more to engineering than taking in information and spitting out solutions" [5].

Worcester Polytechnic Institute offers an introductory course for all engineering students, which focuses on the development of skills such as using software to solve equations, plot data, create drawings, and write reports. The course project was to design

and build a prototype of a sensory stimulation table for an adult man with profound mental retardation, which had to be submitted along with written and oral reports. The remainder of the course consisted of lectures and laboratory sessions, which introduced students to reverse engineering activities. The authors note that one key challenge in designing a first-year problem-based common course is that students in the first year of engineering have typically not been exposed to a course in engineering design. This is why reverse engineering has been used to help students become familiar with the design process. Course evaluations indicated that the class project, hands-on activities, and the emphasis on case studies were well received by the students. However, considerable care must be taken in utilizing and selecting design projects for first year courses. The authors warn that such courses must include mechanisms for rapidly building student experience in design while keeping in mind that they come with no background in engineering. The project has to be simple enough yet motivating and effective [6].

Professors at Michigan State University have integrated their engineering academic program and made it common to all first year engineering students. Among the program requirements are courses based on themes essential to students across engineering: design, engineering modeling, oral and written technical communication, teamwork, creativity, ethics, and professionalism. Another goal for these courses is to demonstrate to students the importance of engineering and the positive impact that engineers make on society and the world around them. In a survey of all engineering students who had taken the course, over 85% agreed that they felt that the course had improved their team skills, and about 70% indicated strong agreement or agreement with improvement in understanding the scope of engineering (applications, careers), development of problem-solving skills, and positive gains in verbal and written communication skills [7].

Miami University also offers first year interdisciplinary curriculum for engineering students. The program includes a one-credit hour course required for all nine engineering majors available. The course is entitled “Computing, Engineering and Society.” The goal of this course is to allow students to “gain an understanding of the work of a professional engineer, appreciate the various engineering majors, experience the engineering design process, develop skills in problem solving, develop teamwork and communication skills, and build community among students.” The course is divided into lecture and laboratory sessions. The main focus is placed on the course project in which students have to design and build a scaled train model layout prototypical to an era and geographic region through which a given train line would operate. The evaluation of the course showed that having an interdisciplinary course where students from various engineering disciplines participate in a fairly realistic engineering experience, which takes them through design in a team environment, is an effective approach in introducing first year students to the fields of engineering [8].

Despite the presence of a wide range of courses that address a common first year engineering class and several that address specific fields in engineering [9], the committee in charge of developing such a course at the American University of Beirut (AUB) is aiming to introduce a new course that inspires creativity in engineering and design, engages first-year students from architecture and various engineering disciplines, and above all provides a multi-disciplinary experience to engineering education.

3. Proposed Multi-Disciplinary Course

3.1. Course Description

The course is designed to familiarize first year students at the Faculty of Engineering and Architecture with the different programs being taught, including: Architecture, Civil, Mechanical, Electrical, Chemical, and Industrial Engineering. It takes a unique multidisciplinary approach to the field, and introduces the related disciplines and the technologies used in the world of engineering and architecture. One key objective is to promote multidisciplinary interaction and innovative thinking. The course is organized into modules covering the different disciplines within the Faculty of Engineering and Architecture. The last module of the class showcases multidisciplinary projects demonstrating interactions among the different fields. The lectures explain, as applicable to each discipline and through examples, notions of problem solving, design thinking, process of invention and innovation, environmental and civic responsibility, and measures of success in aesthetics and performance. The course project is a key component of the course, with a multidisciplinary nature, bringing ideas and solutions from all disciplines in engineering and architecture.

The purpose of the course is to: introduce students to the different engineering professions, provide students with an overview of engineering ethics, present to the students the various areas within each of the engineering professions, promote multidisciplinary interaction and innovative thinking, and foster effective communication and teamwork skills among students.

3.2. Student (Learning) Outcomes:

Students who successfully complete this course will:1) have a realistic understanding of the different engineering professions and the working environment of engineers; 2) develop understanding of engineering ethics and professional responsibilities, and get familiarized with codes of ethics of different engineering disciplines; 3) understand the synergy between different engineering disciplines, and the importance of multidisciplinary collaborations as integral to creativity and innovation; 4) be able to work and function in a multidisciplinary environment; 5) develop understanding of engineering problem-solving concepts and principles; 6) demonstrate an understanding of the engineering design process including problem formulation, constraints, alternatives, prototyping and testing; 7) be able to apply critical thinking and basic research skills to formulate and exchange innovative ideas; 8) be able to integrate knowledge, methods, and relevant information from related disciplines into the design processes; 9) develop an awareness of challenges occurring in teamwork (e.g., task division, communication skills, etc.); and 10) develop presentation skills.

3.3. Course Organization into Multi-disciplinary Modules

The course will be taught in modules. Each department in FEA will offer three 50-minute lectures to cover the following aspects of “Who we are” in the specific discipline, “How we integrate with other disciplines,” and seminars for invited speakers. The instructors are expected to rotate yearly to maintain a level of freshness to the course.

To describe “Who we are,” each department’s lectures will first introduce the program and the disciplines within the department. Students are informed about different

programs and related professions. Each instructor will then cover description of the discipline curriculum. Finally, professors will share their experience and introduce their work. Light and informal lectures are provided, where students can be inspired by guest professionals who share their personal experience and showcase their work.

To describe "How we integrate/interact with the others," each department's lecture will present cases that involved engineers or architects from other fields, explaining how they impacted the process and the quality of the product. Students have the opportunity to hear versions about the profession from different perspectives. Each lecture aims to bring out interdisciplinary aspects with other fields and technology.

The course will also include a module providing an introduction to Codes of Ethics and Professional Standards. This module prepares engineers and architects for understanding the ethical expectations of the profession.

One module will also be dedicated to expose the students to hands-on technology experience. The labs are meant to be fun and challenging, yet without requirements for any particular background. As an example, the students may be asked to develop specific designs with Lego Robotics integrating elements of design, architecture, programming, mechanical, and civil engineering. The hands-on experience with engineering tools is meant to support the use of technology and design, covering general engineering and architecture concepts that are not necessarily specific to a particular area.

3.4. Course Project:

The course entails two projects that together provide the students with the necessary skill-set and learning outcomes of the course. One project teaches students about the basics of robotics, sensors, actuators, communication, computer software and hardware, and embedded control by building a robot that contends with other robots in a competition format. The second project teaches students about design innovation, originality, complexity versus simplicity, functionality, aesthetics, and economy of means by building a bridge. Performance assessment measures performance on the aforementioned criteria. Both projects foster collaboration, team work, multidisciplinary approach, time management, and effective communication skills.

Course projects are an essential component of the course. The goal of the projects is to encourage students to be creative and innovative, understand the multidisciplinary nature of engineering and architecture, relate aspects of the project to the different disciplines in FEA, discover their own skills and strengths, apply concepts and approaches learned, and work with teams of different FEA disciplines.

Students are assigned to groups. Where possible, each group of students must be constituted of at least one student from each department. Each group will be assigned to a faculty jury committee. The types of projects are intended to cover technology while being fun (e.g. based on Lego Robotics), or open fostering creative thinking (e.g. building bridge, robot competition, dropping eggs, etc.). Projects may not necessarily require their physical presence in a lab. Students work on project 1 in the first half of the semester and on project 2 in the second half.

Projects will go through trial and error before maturity, and they are intended to be self-driven by the students. Lab instructors will be assigned to specific groups, and will post their availability to the students. Professors (class instructors) are available during office hours for additional consultation if needed.

3.5. Course Assessment

Student performance shall be evaluated as Pass/Fail based on the following strict criteria: project contributions, class attendance, and lab evaluation. For project assessment, each the team is required to reflect innovative input, teamwork, and understanding of the project and hence each team is assesses based on these criteria. Each faculty committee member will give a Pass/Fail evaluation at the end of semester for the groups they oversee. They would also nominate exceptional projects for further competition and awards. A competition will be held with the nominated groups, and finalists are awarded. Up to four awards may be awarded per semester. Competition jury is the same as the coordination committee or designates, if they choose.

For class assessment, attendance is mandatory and required in every class, where students would be penalized for absences exceeding four sessions. The student may seek to be exempt from counting a particular absence by presenting a petition along with a documented valid excuse explaining the absences, to the course committee. Attendance will also be subject to university regulations. For example, at the American University of Beirut, students who miss more than one-fifth of the sessions of any course in the first ten weeks of the semester will be required to withdraw from the course with a grade of "W."

For Lab assessment, each team will be assessed for Pass/Fail based on their contribution and learning in Lab work and assignments.

4. Conclusion

This paper discusses the theory, pedagogy, and multidisciplinary approach of designing an introductory course in engineering and architecture at AUB. The new course is designed to meet the needs of future engineers and architects, and their employers, to help them develop multidisciplinary skills, teamwork spirit, professional ethics, and effective communication skills. It is designed to enhance the students understanding of the various programs offered at the FEA, how they complement each other, and which discipline is the right fit for them.

The course is aligned with the new trend in education where students from different backgrounds are constantly engaged on multidisciplinary teams and challenged to operate in environments that require collaboration, innovation, and problem solving. While many leading academic institutions have adopted this trend, AUB is championing the movement in Lebanon and the region. Although many similar courses exist in engineering schools around the world, this can be considered one of the world's first courses addressing both engineering and architecture disciplines in one introductory course that takes a multidisciplinary approach while encouraging creativity and innovation in education. .

The course meets the basic requirements of the involved departments as well as some requirements of the ABET accreditation system. Measures are taken and metrics are defined to assess students learning outcomes. Future research will present actual results describing the performance of the new course as well as lessons learned from teaching the course to engineering and architecture students at AUB.

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Message from Khaled Chehab
President of the Federation of Lebanese Engineers

It is a great honor to welcome engineers from all countries to the 10th World Congress on Engineering Education (WCEE 2015) "Engineering Education for sustainable Development" in Beirut, Lebanon.

The theme of this Congress is versatile and it will be a great opportunity for authors and educators from all over the world to discuss the different visions related to the engineer' s education.

I wish a full success to this gathering and to the future of Engineering Education.

The World Federation of Engineering Organizations

WFEO serves society and is renowned as a respectable and valuable source of advice and guidance on the policies, interests and concerns that relate to engineering and technology. The role and responsibility of engineers in addressing the challenges facing society is more recognized and acknowledged worldwide.

The World Federation of Engineering Organizations (WFEO) is the sole body representing the engineering profession of all kind and disciplines.

Committee on Education In Engineering

The aim of the Education in Engineering Standing Technical Committee (CEIE) is to work for the development of the profession and to work toward the mobility of Engineers around the world. Its aim is to become one of the accreditation agencies for the engineering programs, working together with other international agencies.