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Remote Teaching Robotics Design Project

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Work In Progress: Remote Teaching Robotics Design Project

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Abstract

A first-year mandatory engineering project-based course aimed at developing an engineering mindset was taught through students engaging in active learning strategies built on the design-thinking framework by Ulrich and Eppinger. Course outcomes were evaluated via student's participation in the fabrication of an autonomous robotic vehicle facilitated through practical hands-on activities, group discussions, and laboratory modules. Due to the COVID-19 pandemic, this previously in-person course adopted a synchronous teaching model and used online instructional tools for lectures, group activities, and project support. The robotic project helped introduce students to engineering principles by employing multi-developmental phases for creating a robot. The teaching approach also provided students an engineering design experience while working in interdisciplinary teams with members serving unique engineering roles such as design, hardware, software, project, or testing lead. Students were required to design and fabricate a relevant prototype for stakeholders and, while doing so, learn and acquire essential competencies and skillsets relevant to engineering professions. Course methodology involved weekly assignments and the acquisition of project kits. The engineering mindset is being assessed through content knowledge of inclusive modules in electronics, programming, 3D printing, innovation, and data analysis assignments. Learning outcomes include using software, hardware-based technologies, and research-based inquiries to design, fabricate, test, and improve an autonomous robot. This remote course structure aims to foster an engineering mindset, technical know-how, innovation and promotes essential competencies like teamwork, leadership, and critical thinking.

Introduction

Robotics has tremendous use in education and has helped improve daily life operations. Further advancement in miniaturization, automation, lightweight, and artificial intelligence technologies are at the forefront of current research for long-term usability [1-2]. Manufacturing robots as a pedagogical practice supports student learning in different entities of the engineering field. Prior to the COVID-19 pandemic, limited studies explored the impact of remotely teaching robotics on pedagogy for replacing or supplementing theoretical courses and traditional hands-on laboratories. Assessment of remote teaching on student performance has revealed online labs as effective learning environments [3-4]. This paper reports a robotic design project framework taught remotely in a first-year engineering lab course. The work presented can serve as a model strategy for teaching any design-based project course online.

Course structure and Methodology

The Foundations of Engineering lab, EGN 3000L at the University of South Florida (USF), is a three-credit course focused on the design process developed by Ulrich and Eppinger [5-6]. Incoming and transfer engineering students are required to take the course in their first year at the college of engineering. Enrollment exceeds 500 students per semester, with up to 90 students allowed per section. Each section is staffed with a faculty member and up to three teacher assistants (TAs).

Course methodology utilized a thematic learning approach by way of a robot design to teach first-year students the fundamentals of engineering. Educational materials covered essential topics for conceptual design and fabrication of a robotic car. The introduction of materials occurred through fifty percent

synchronous lectures followed by practical online activities (50%). Topics covered include Design Thinking, Computer-Aided Design (CAD), Fabrication method, Programming, Concept sheet generation, Instrumentation, Design Optimization, and some soft skills activities not presented in Table 1. The learning outcomes for this course include software (e.g., CAD and Arduino IDE) and hardware training (e.g., circuits, breadboards, sensors, 3D printers) and research-based strategies (e.g., Design Heuristics, Engineering Design Process) to design, fabricate, test, and optimize an autonomous robot. All students in the course were required to purchase the Elegoo Uno Project Super Starter Kit from Amazon.

Students were required to create novel autonomous robotic cars in teams of up to five members and each assuming individual lead roles. Execution of project assignment occurred via members completing their respective tasks as the Project Engineering lead, Test Engineering Lead, Software Engineer Lead, Design Engineering Lead, and Product Development (hardware) Lead. Students self-select into these roles with the possibility of switching up until the first group assignment.

Table 1: Overview of Topics Covered in First-Year Engineering Design Course

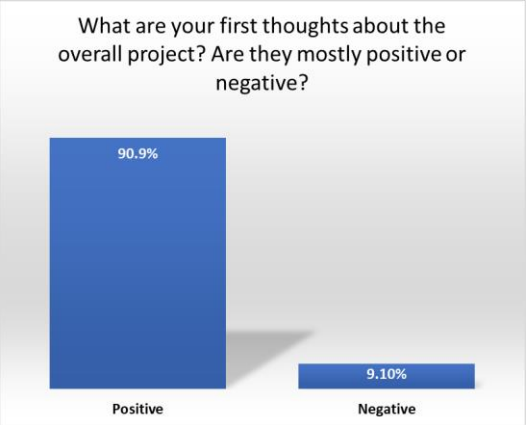
Modules	Lab Activities
Engineering Design-thinking Ulrich and Eppinger's Design Process	TinkerCAD tutorial
Robotics Manufacturing Technology Introduction to 3D printing	Cosmetic Design
Programming Tools	Arduino Programming worksheet
Ideation to Fabrication Introduction to Design Heuristics	Iteration Concept sheet Fabrication Worksheet
Robotics Instrumentation Electronics & Sensors	Circuit tutorial Electronics worksheet
Robotics Design Optimization Engineering Data Analysis	Design Optimization Survey Value Creation
Project Showcase competitions	Robotics Design presentations

Groups with access to campus had the opportunity to print parts for their robots using the 3D printers available at the University's Design for *X* lab, a maker space designated for engineering students to tinker and use various engineering tools. At the end of the semester, groups presented their finished prototypes in an online showcase competition. All instructors teaching the course formed the judging panel to evaluate section finalists for the top three best robotic car prototypes.

Course benchmarks focused on responses from student evaluation surveys and performance on the final project showcase. Three sets of surveys not listed in this paper were conducted to assess students' perceptions of the course. First, pre-course questions gathered students' location and preferred team role assignment in the first week of classes. Students were then paired into a team of up to 5 students based on their survey entries. The second survey was conducted during the mid-semester to analyze students' experience in the course with the intent to circumvent any pitfalls before the completion of the project. The third survey evaluated student perceptions of the course, robotic project, team assessment, and self-reflection using an adapted form of the Wabisabi Learning 25 Self-Reflection questions.

Results and Discussion

In the COVID-19 pandemic, the EGN3000L course adopted a new structure to facilitate replicating in-person conditions and activities that support online learning. The objective was to have students gain a technical competency per module (Table 1) using a thematic approach of robotics technology. Course learning outcomes such as developing an engineering mindset, teamwork, and critical thinking skills were centered around learning to manufacture an autonomous robotic car. A project work order was shared detailing the engineering specifications and customer needs relevant for K-8 stakeholders. By the end of the course, students were required to present a functional prototype of their cars in an online showcase competition event. Overall, approximately 91% of those students found the robot project positive and engaging, figure 1.



Students desired face-to-face classes, especially hands-on lab activities. Students requested more in-depth teaching of programming, which may or may not be limited due to teaching online. Anxiety and fears of presenting online and demonstrating their working robots were students' primary concerns. Working in a supportive team helped accomplish tasks effectively; however, communication and scheduling were the two main deterring factors mentioned mid-semester.

Figure 1: Students' thoughts about the synchronous online robotics-based project course..

Conclusion and Future direction

The robotic project-based learning approach introduces students to engineering by employing the different multi-developmental phases of creating a robot. Construction of robotics design from theoretical aspects of programming, fabrication, project design process, and electronics tinkering could lead to fruitful student learning outcomes. Future work includes a report of the survey instruments, a quantitative evaluation of the pedagogical impact of remote versus in-person learning and instruction, a discussion of the encountered challenges, and the best teaching practices for a robotics course.

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