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Inspiring Makers in First-Year Engineering under Emergency Remote Teaching

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ABSTRACT

The First-Year Cornerstone Engineering Design Project Course (ENGG1100) aims to maintain practicality and excitement of experiential learning by enabling students to create an authentic artifact, despite the unexpected shift to emergency remote teaching due to COVID-19. The main challenge is to teach a course that usually takes place in a makerspace and to redesign it to enable students to be a "maker" at home. The course was well-received based on student feedback. This experience is an important step to understand the possibilities and limitations of teaching project courses entirely online.

Key words: first-year engineering, multidisciplinary design, active learning

INTRODUCTION

Since the early 1980s, first-year or cornerstone design courses have gained increasing attention in first-year engineering curricula (Froyd, Wankat, and Smith 2012; Dym et al. 2005) and have remained a well-recognized approach to develop skills to address engineering challenges in the 21st century (Miller 2015; Bazylak and Wild 2007; Marra, Palmer, and Litzinger 2000). Prior studies have shown that engaging first-year engineering students with full-scale, authentic, hands-on projects has a positive effect on their intellectual development (Dym et al. 2005; Marra, Palmer, and Litzinger 2000), engineering identity (Whitfield et al. 2011; Saterbak and Wettergreen 2016; Goodrich and McWilliams 2016; Marshall et al. 2018), motivation (Dym et al. 2005; Saterbak and Wettergreen 2016), and retention (Froyd, Wankat, and Smith 2012; Dym et al. 2005; Goodrich and McWilliams 2016; Marshall et al. 2018). The First-Year Cornerstone Engineering Design Project Course (ENGG1100) aims to maintain practicality and excitement of experiential

Figure 1. Introduction video to ENGG1100 for regular offerings. Source: Available at: https://youtu.be/gdnFo2imepc.

learning by enabling students to create an authentic artifact, despite the unexpected shift to Emergency Remote Teaching (ERT) (Hodges et al. 2020) due to COVID-19. The main challenge is to teach a course that usually takes place in a makerspace and to redesign it to enable students to be a "maker" at home.

In regular offerings, the course uses a blended experiential learning approach. Students are presented with an open-ended design problem. Through an online platform called HKMOOC[1], they acquire multidisciplinary knowledge and technical skills individually, then build an artifact (e.g., an airship or a chemical-battery vehicle) as a team. Students practice the engineering design process (Plan and Khandani 2005) with multi-level feedback from instructors, senior students, and peers. HKMOOC includes lecture videos, quizzes, assignments, and supplementary information for discipline-specific modules including mechanics, programming and electronics. Students test and refine their prototypes in a makerspace. The course ends with a competition, increasing students' excitement to its maximum. This competition is their final assessment, and allows the students to appreciate others' efforts. However, their grades are not awarded on this single event, but also on their ability to reflect and their attempts to improve throughout the process.

METHODS

Unlike online learning, ERT is not intended to replace the regular method of instructions, but to prepare for "a temporary shift of instructional delivery to an alternate delivery mode" (Hodges et al.

[1] Hong Kong Massive Open Online Courses (https://learn.hkmooc.hk/)

Table 1. Migrated, changed and new content in regular offering and ERT.

	Regular offering	ERT
1) Migrated content		
Online modules	Using HKMOOC to deliver basic knowledge in mechanics, electronics and programming	
2) Changed content		
Venue/Platform	Makerspace	Zoom
Project kit	Available in Makerspace	Parcel delivery
Project materials	Available in Makerspace	Household/recycled items
Engineering disciplines	Mechanics, electronics, programming, chemistry, 3D printing	Mechanics, electronics, programming, 3D modeling
Project aim	Build a chemical-battery powered vehicle	Build a propeller-driven vehicle (air-car)
Project output	Per team	Per student
Rapid prototyping exercises	1-balloon airship, sail car	Mask design, homemade visualizer
Prototyping demonstration	Live in-class	Live in-class plus extended period for video submission
3) New content		
Individual feedback		Simultaneous demos, consultation sessions in small groups
Learning by reflection		Recordings playback

2020). As a result, the course design and implementation were changed to accommodate this online setting. To facilitate understanding, a comparison between the new and regular method is presented in Table 1, with three categories: 1) migrated content, 2) changed content, and 3) new content.

Forty-one students were enrolled in this course. We used Zoom[2] to conduct synchronous classes, each class lasting 3 hour per week. All sessions included a mix of instruction, feedback, and small group discussions. All students were divided into teams of four or five.

The design project was based on the construction of an "air-car" – a vehicle equipped with propeller(s) for driving and steering, programmed by Arduino, and controlled remotely using an Android device. We tested the feasibility of building such a vehicle with the components provided to ensure that the project offered enough variation and difficulty to achieve the learning objectives. The students needed to acquire knowledge from the online modules and apply it in practice. The electronic components were packaged in project kits and mailed to the students locally and overseas. As shown in Figure 2, the kit included the components necessary to assemble an electrical circuit to control the speed and direction of two propellers with an Android device. The students used household or recycled materials to build the vehicle body. In addition, each had a budget (approximately US$25) to purchase batteries and building materials. Later, we received reports of broken and faulty parts and sent a replacement batch.

[2] Zoom conference online platform: http://zoom.us

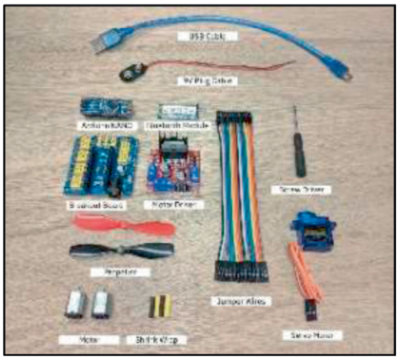

Figure 2. Components of the project kit.

The students were asked to perform three live demonstrations of their progress via Zoom throughout the semester (see example in Figure 3). The first time was to present their assembled circuit and application, the second was to show their first prototype, and the third was the last session during which they were required to co-operate and perform a timed-relay race (see Figure 4). These demonstrations were intended for assessment purposes and more importantly, for the students to see each other's progress, failures, and successes to facilitate peer learning. The ability to see the work of other students was essential because the students were mainly working alone at home throughout the semester. In the event of a poor Internet connection or hardware issues, video submissions were also accepted with extended due dates.

In addition to the main project, rapid prototyping exercises were conducted in class. The students worked in teams and proposed solutions such as "a new mask design to address the supply shortage"

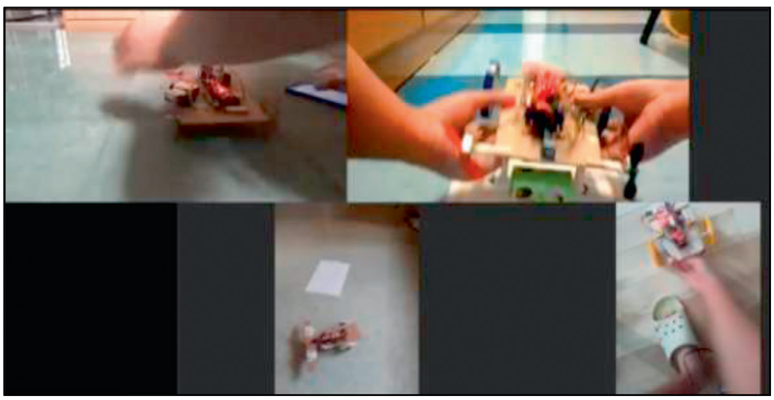

Figure 3. Prototype demonstration via Zoom (right). Source: Available at: https://youtu.be/anM6ohxUbNM.

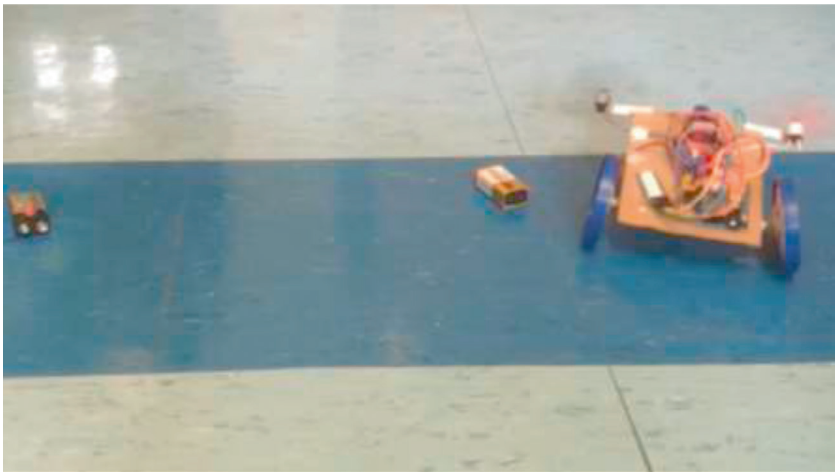

Figure 4. Final demonstration video. Source: Available at: https://youtu.be/ndb174ML6hE.

or “a homemade visualizer for Zoom discussions”. These exercises were intended to articulate their interest in engineering design and to guide them through the engineering design process.

PRELIMINARY RESULTS

Among the 41 students, 29 successfully constructed a working air-car (see examples in Figure 5). The other 12 students encountered hardware issues or workmanship problems or their designs were

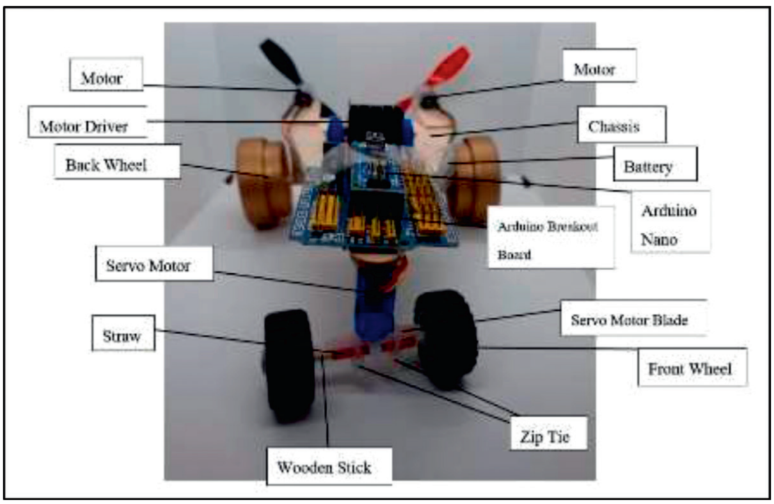

Figure 5. Example of a student’s submission of an air-car.

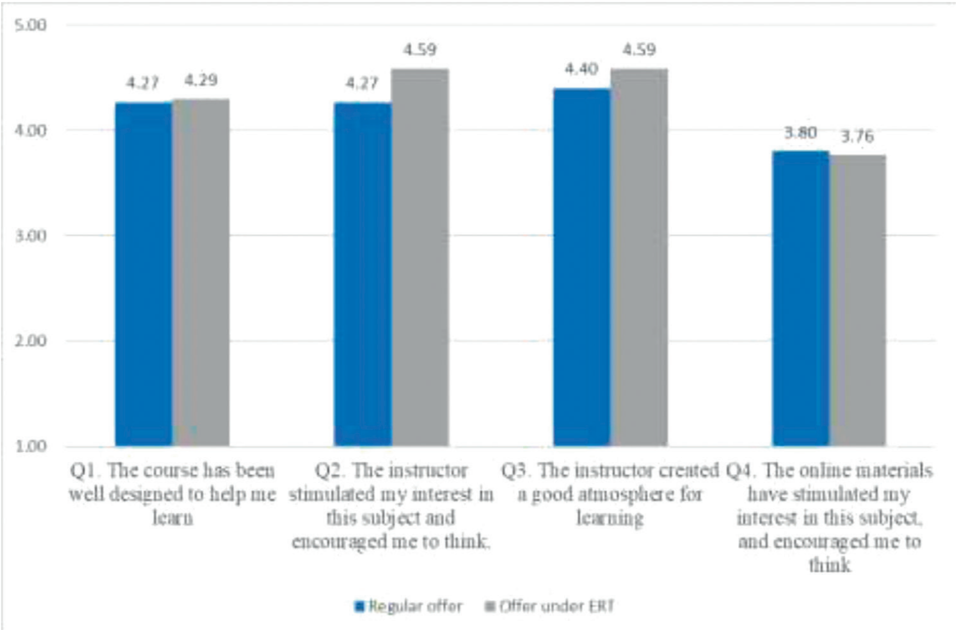

Figure 6. Comparison between student ratings for regular offerings and ERT.

not feasible. Compared with regular offerings in which most teams generally complete their project, this result can be explained by the fact that the students did not have access to the tools in the makerspace and to the advice of their instructors. However, the assessment did not only consider the performance of the vehicle, but also whether the students had the ability to identify the problems and explain how they tried to solve them.

Figure 6 shows a comparison between the student ratings for the course offered in regular semesters and in ERT, with response rates of 43% and 41%, respectively. The students rated their level of agreement with each statement on a 5-point Likert scale (1 – *strongly disagree*; 5 – *strongly agree*). All mean scores higher than 3 were interpreted as edging toward positive, and vice versa. The questionnaire consists of 22 items, with closed-ended and open-ended questions. However, only four items are shown in Figure 4 because the other questions cannot be compared; for example, items related to face-to-face discussions and activities are not comparable.

The students from both groups had similar ratings for item 1 ("The course has been well designed to help me learning") and item 4 ("The online materials have stimulated my interest in this subject and encouraged me to think"), whereas the ERT course received higher ratings for item 2 ("The instructor stimulated my interest in this subject and encouraged me to think") and item 3

("The instructor created a good atmosphere for learning"). For the open-ended question about the students' opinion on the course, many said that it was challenging but that they had learned a lot from the experience:

"[…] It is hard, but worthwhile."
"it is fun to build something by hand […]".

NEXT STEPS

The results are encouraging. The course was well-received based on student feedback. The advantage of not requiring a physical space and access to machinery made the class possible to scale-up. However, many assumptions were made when trying to find a suitable project that could be done at home. For instance, asking the students to purchase batteries to power their vehicles raised some concerns because the cost and accessibility of batteries may vary by locations. In terms of course budgeting, the project kits were also expected to be returned once classes returned to normal.

In summary, this semester was difficult, and both students and instructors made great efforts to engage in learning and teaching activities through an unfamiliar medium. This experience is an important step to understand the possibilities and limitations of teaching project courses entirely online; for instance, certain content must be taught in-class in a makerspace environment. We look forward to refining our teaching resources for longer-term implementation.

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APPENDIX

Link to teaching resources:

https://gohkust-my.sharepoint.com/:f:/g/personal/egjac_ust_hk/EihBeCkb4BxAvNJVCt6B6hkBFiwljM4vCdQSRhCUysPbjg?e=gDyv4e

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