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Integration of 3D printing in computer-aided design and engineering course

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ABSTRACT

Engineering students at an undergraduate level typically learn the design aspect and concept through lectures and practical sessions using computer-aided software. However, the current computer-aided design and engineering (CAD/CAE) course did not expose the students to apply and relate the latest advanced technologies to solve global issues, for instance as listed in the United Nations Sustainable Development Goals (UN SDG). Therefore, an improved CAD/CAE course taken by the students of the Electrical and Electronic Engineering Programme in Universiti Kebangsaan Malaysia integrates 3D printing and conduct their project based on UN SDG themes. A total of 22 projects was produced, which involves both mechanical and electrical design with some of the physical models were 3D printed. Thus, students able to strengthen their understanding of the design concept through the integration of 3D printing and simultaneously aware of the current global issues.

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1. INTRODUCTION

Producing dynamic graduates who aware of the current global issues and latest technologies is one of the challenges faced by universities and higher education institutes, especially for the engineering field [1, 2]. Therefore, the engineering design course becomes one of the courses that can realize this challenge. Typically, design course students learn the engineering design aspects through theoretical and conceptual learning in lecture sessions [3–5]. Then, students practice those theories and concepts via laboratory sessions using computer-aided software.

At the same time, all graduated students should be an individual who can adapt to life-long learning upon graduation [6, 7]. They must be aware and able to tackle problems related to the current global issues as mentioned in 17 Sustainable Development Goals (SDG) stated by United Nations (UN) and ready to apply their engineering knowledge to handle those SDG challenges [8]. Besides, university courses should expose students to the latest technologies such as three-dimensional (3D) printing, which is one of the main pillars in the Fourth Industrial Revolution (IR4.0) [9–14]. Several works integrate this 3D printing technology, especially in science and technology, medical and special education [7, 15–22]. Nowadays, 3D printed parts act as supporting tools for educators [23–28]. For example, medical education courses use 3D printed models in their teaching and learning (T&L) process [29–33]. On the other hand, many works show that the T&L

process utilized different kinds of technology to assist the students to enhance their understanding and involvement [34–37].

Therefore, this paper describes a T&L practice in Universiti Kebangsaan Malaysia (UKM), which integrates 3D printing technology in the engineering design course. In specific, the involved course is the Computer-Aided Design/Computer-Aided Engineering (CAD/CAE) course with a course code of KKKL1103. All first-year undergraduate students of Electrical and Electronic Engineering Programme in Faculty of Engineering and Built Environment, UKM, are compulsory to take this course during the first semester of their four-year study.

2. RESEARCH METHOD

In detail, a total of 106 students took the CAD/CAE course in Semester 1, Session 2019/2020, which finally formed 22 groups of students. Each group proposed and designed a project based on one of the 17 UN SDG using their knowledge learned either through lectures or laboratory sessions. This project aims to establish awareness to the students on the current global issues such as social, environmental, and economic problems. Besides, each project combines both mechanical and electrical part designs, even though those students enrolled in the electrical and electronic engineering field. The purpose of this combination is to develop them as multidisciplinary engineers of professionals that able to cope with real-world challenges. Next, each group must produce a physical model using 3D printing technology.

Throughout the project, students use various software to complete their projects. Students used AutoCAD software from Autodesk to design the mechanical parts by drawing several multiview and isometric drawings in 2D and 3D forms. Meanwhile, students also utilized OrCAD software from Cadence to design the electrical and electronic circuits. After that, each group converted the circuitry into the printed circuit board layout to obtain the electrical part dimensions. Then, an assembly drawing combines both mechanical and electrical parts, similar to the manual of electrical and electronic products. Finally, each group printed some mechanical parts from their project using a 3D printer, model Snapmaker 3-in-1, as shown in Figure 1, using SnapmakerJS software.

Figure 1. 3D printer model snapmaker 3-in-1

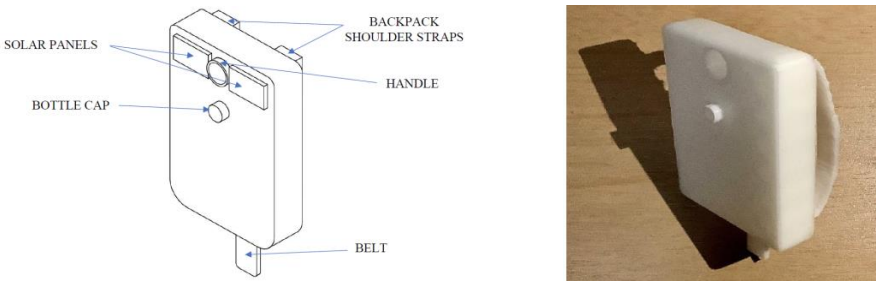
3. RESULTS AND DISCUSSION

Overall, a total of 22 projects have been designed by the students based on UN SDG. Table 1 lists all project titles and corresponding UN SDG. UN SDG 6 (clean water and sanitation) is the most selected theme which is 36.4% from all projects. Meanwhile, UN SDG 4 (quality education) and UN SDG 7 (affordable and clean energy) are the least chosen themes with only one group. This outcome shows that UN SG 6 is the theme that relates directly to the student's current knowledge. This aspect is also important for their life-long learning in the future after graduation [1, 6].

Table 1. List of the project title and theme related to UN SDG

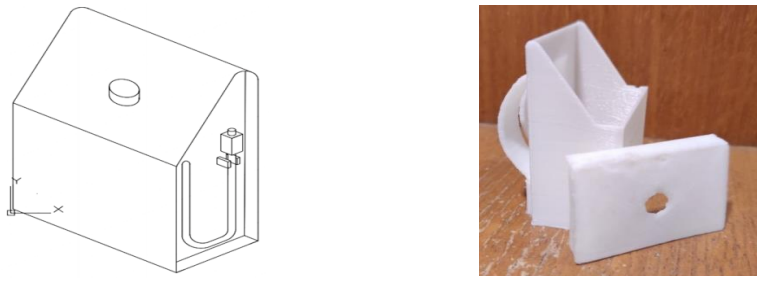
ti	Project title	UN SDG theme
1	Thermo hydro-sack	SDG 6
2	Food waste grinder	SDG 6
3	Multifunction easy use desk	SDG 9
4	Heat sensor	SDG 16
5	Burglar alarm	SDG 16
6	Turbidity	SDG 6
7	Foldable trolley	SDG 4
8	Smart umbrella	SDG 11
9	Automatic water quality detector	SDG 6
10	Automatic pharmacy	SDG 3
11	Resident lift	SDG 11
12	Health watch	SDG 3
13	Fingerprint door lock	SDG 16
14	Portable turbine	SDG 6
15	Flood detector	SDG 11
16	Solar-powered water purifier	SDG 6
17	Water bag	SDG 6
18	Eco-bin	SDG 11
19	Piezoelectric tiles power generator	SDG 9
20	Power plug	SDG 7
21	Sewage scout	SDG 6
22	Foldable chair	SDG 3

Furthermore, Figure 2(a) shows an example of engineering drawing drawn using AutoCAD software, while Figure 2(b) depicts the actual mechanical part printed using the 3D printer. This type of project, which involves 3D printing prototypes is common in undergraduate study levels [7, 12]. Chong [7] reported 46% of their project requires students to fabricate actual 3D printing parts. Meanwhile, Poudel [12] showed that students able to write up documentation on their 3D prototype projects. Besides, Figure 3(a) and Figure 3(b) shows another example from the other group. These outcomes prove that the students able to strengthen their understanding of the theory and concept by fabricating some of the mechanical parts in the project using 3D printing technology [3, 24, 25]. Chiu [3] stated that student's creativity increased after learning 3D printing technology.



(a) Engineering drawing (b) Actual part

Figure 2. The first example of 3D printed parts



(a) Engineering drawing (b) Actual part

Figure 3. The second example of 3D printed parts

4. CONCLUSION

Integration of 3D printing in the computer-aided design and engineering course able to expose the students to the application of the latest technology, which eventually strengthens their understanding by fabricating the actual part. This experiential learning improves their critical thinking and psychomotor skills. Besides, other engineering courses should integrate other pillars in IR4.0 and UN SDG in the future to enhance student performance and awareness of local and global issues.

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