Empowering teaching and learning for Industry 4.0 through development of open source 3D printing project

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ABSTRACT – 3D printing is one the essential thrust of 4th Industrial Revolution (IR 4.0) and therefore, future engineers should be equipped with the know-how knowledge of the 3D printing. However, the number of 3D printers during teaching and learning relatively are low and the usage of the machine need to be strictly controlled due to other constraints such as high cost, maintenance, etc. The project overcomes the shortage of 3D printer for teaching and learning by developing open source 3D printer as a project-based learning. As a result of this project, the number of the 3D printers have been increased and student understandings are enhanced.

1. INTRODUCTION

The 3D printing is a process to obtain the physical three-dimensional (3D) model data through the layer-by-layer solidification of the material. The 3D model is developed and constructed with the aid of the computer-aided design (CAD) system, which serves as the basis for the manufacturing process. Unlike traditional manufacturing methods, 3D printing offers a short lead time to fabricate parts and improved design flexibility.

Industry 4.0 changes the landscape of manufacturing industries to ensure companies to be more efficient and productive parallel with global trends. 3D printing is one of the components interrelated as the main pillars of industry 4.0. Besides that, SME Corp Malaysia highlighted that some tipping point of technological shift expected to occur by 2025 [1]. Thus, expertise in 3D printing is an added advantage for a future engineers. Teaching and learning at the tertiary level on TVET must be able to enhance student knowledge by doing hands-on. Taiwan's Ministry of education, for example, has redesigned the high school curriculum by including the design course using 3D printing technology [2][3].

Teaching and learning course using the open source 3D printer may serve as a project-based learning and hands-on curriculum for students to experience the real engineering application in smaller scale. Open source 3D printer such as RepRap and Fab@home enables the use of design for anyone to build, which are economically made from readily available resources. This is not only able to reduce in cost but also able to increase the level of innovation among the students. The basic step to develop open source 3D printer was divided into mechanical design, electronic component, configuring and compiling marlin firmware and control software. This project is inspired by more advanced application as reported by Rosli et al [4]. Nevertheless, necessary changes have been made for teaching purpose.

This project attempts to explore the development of the open source 3D printing project as a mean to develop and increase student understanding of the technology and at the same time solve the problem faced in teaching and learning using 3D printing due to high cost and limited number of machine available in the laboratory.

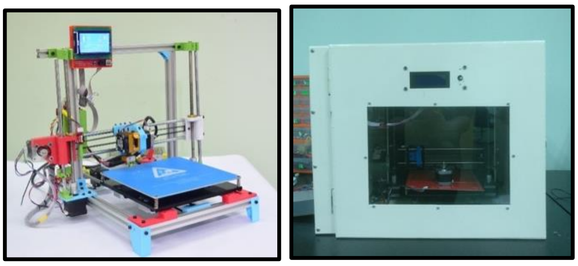
2. METHODOLOGY

During teaching and learning process, students were divided into a group of four, and each group was facilitated to develop an open source 3D printer. In a group, the design generation was constructed based on their own specification of 3D printer and the best design was selected and evaluated. Two methods that mainly used to evaluate the design is Pugh method and weighted decision matrix. The best design concept has been selected for further development process. Next, the mechanical component selection of component such as threaded rod, linear bearing, belt, extruder, smooth rod, aluminium extrusion, heat bed and others were made based on their design. Certain mechanical and assembly components were fabricated using other 3D printer or machining process. Then, the parts were assembled, and followed by calibration and testing.

In order to confirm the effects of the project to the overall student satisfaction, a survey was conducted to 39 students in the class by using a google form. Questions were asked to the students and likert scale was used with the option of Absolutely Yes, Maybe, Not Sure, No Ideas or No can be selected by the students. Based on this survey, the understanding and satisfaction of the student on the approach used is analysed.

3. RESULTS AND DISCUSSION

Figure 1 indicates the completed 3D printers that have been developed by the students during the teaching and learning process. The figure indicates different design that has been selected and fabricated in the project. The figure shows the 3D printers with and without enclosure.



(a)Without casing (b) With casing

Figure 1: Completed open source 3D printer

Before the project was implemented, teaching and learning utilized commercial 3D printing. As the number of the commercial 3D printers is limited, the number of students per group are high. The students also have to queue to use the machine. In certain cases where the complicated parts are printed and time consuming, only demonstration is possible in order to reduce the cost and printing time. This is illustrated in the Figure 2. However, after implementation of the project, students have more time to explore and experiment using the machine that they have developed on their own.

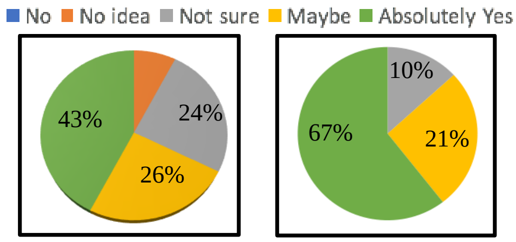
(a) Before project-based learning - Demo and simple product fabrication

(b) After project-based learning - students build their own 3D printer

Figure 2: Teaching and learning in laboratory

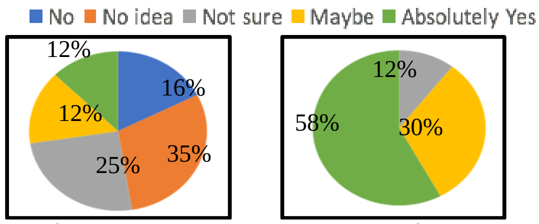
Based on the survey, the results obtained are as indicated in the Figure 3 and 4. The results indicate that generally the students are satisfied with the project and newly developed 3D printer in enhancing their understanding. Figure 3 depicts the students response on the question effectiveness of learning process. It was found that 67% student absolutely agree compared to 43% before the project was implemented.

Another question related to the student satisfaction on the amount of time that they are able to use the machine during the teaching and learning process. It was found that 58% of the students agree that they have enough time to operate the machine in comparison to 12% before the project. New skill and knowledge are obtained by the students since all members need to learn something new and spent a lot time to understand the technical part of machine development and troubleshooting.



(a) Before project (b) After project

Figure 3: Survey on student satisfaction of teaching and learning effectiveness



(a) Before project (b) After project

Figure 4: Survey on student satisfaction on contact time with the machine

Therefore, in general, the satisfaction of the students and their understanding is increased after the project implementation.

4. CONCLUSION

The main benefits that have been achieved by the project are cost saving for expensive commercial machine and an improved student understanding and satisfaction during teaching and learning process. The project may also enable new project related to consultation, income generation, training, research, community service and others can be made using the new machine at lower cost.

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REFERENCES

[1] R. Nainy. (2017). Industry 4.0 and its implications to SMEs. *SME Corp Malaysia June*, 1–37.

[2] Chien, Y. (2017). Developing a Pre-engineering Curriculum for 3D Printing Skills for High School Technology Education. *EURASIA Journal Of Mathematics, Science & Technology Education 13(7)*, 2941-2958.

[3] Greenhalgh, S. (2016). "The effects of 3D printing in design thinking and design education," *Journal Of Engineering,Design And Technology 14(4)*,752-769.