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INTRODUCTION OF 3D PRINTING INTO MARINE ELECTRICAL ENGINEERING EDUCATION – A CASE STUDY

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Abstract. The research on 3D printing aboard ships is already under way. The private sector and the navy are both experimenting with its usage. This type of education is however missing in mariner education (e.g. Electrotechnical Officer) and in International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) alike. Various authors have proposed that 3D printing should be included in the STCW standard courses. This paper describes an example of introduction of 3D printing into marine electrical engineering education at the Faculty of Maritime Studies in Split. The class is mandatory for this study. This is performed through "learning by doing" technique.

Keywords: 3d Printing; electrotechnical officer; mariner education; problem based learning; spare parts

Introduction

Additive manufacturing is advancing field, which is present more and more in everyday life. Hence it is expected to be included in modern curriculums (Kumnar et al. 2020). Examples of new technologies introduction into educational process is a topic of many papers, i.e. augmented reality (Yüzüak et al. 2020) or internet of things (Alharbi 2020), and improvements in laboratory exercises is reviewed in (Mohan et al. 2019). Implementation of 3D printing into education is addressed in (Jaksic 2016; Sharif et al. 2020)

Low-cost 3D additive manufacturing has become quite popular and this technique is developing very rapidly, with seemingly unlimited potential. Today, 3D printing technology is capable of reproducing 3D objects from complex mathematical surfaces with the process including rapid prototyping. All in all, the technology has an exceptionally promising future. The current expansion of 3D technology has benefited from the expired 3D printing patents for Fused Deposition Modelling (FDM). The 3D printing technology builds up objects layer by layer. Objects are produced using wheels of plastic filaments made either of PLA (Polylactic acid) or ABS (Acrylonitrile butadiene styrene). The PLA has the advantage of being biodegradable, hence environmentally friendly since it is made from cornstarch while the ABS polymer is obtained from fossil fuels. 3D printing using plastic material is limited by available dimensions for printing, typically 20x20x20 cm, due to the low cost of equipment[1]. Large 3D objects can be constructed using smart design, by facilitating the assembly of many small plastic parts into a single, large object.

There is a clear opportunity to improve Science, Technology, Engineering and Mathematics (STEM) education by using low-cost 3D printers. Such 3D printing makes possible a transition from theory to practical realization. Physical objects manufactured can be touched, thereby allowing students to work with modern, cutting-edge tools. This kind of technology fosters student-driven learning. The learning process benefits from such design and manufacture due to a self-driven educational setting based on Schelly's (Schelly et al. 2015) which suggests that students engage the most when allowed to actually do something, rather than just listen to a lecturer.

The vital question here is: why do we need 3D printing in seafaring? This field is being increasingly studied currently. Acceptance of 3D printing in the maritime industry has been explored in (Knulst 2018). A pilot project involving the use of 3D printed spare parts is presented in Pilot project (2016)[2], while spare part management using this technology is explored in Pour and Zanoni (Pour et al. 2017). An example of 3D printing technology in oceanology is elaborated in (Mohammed 2016). Even social aspects of this technology have been considered by Jiang et. Al. (Jiang et al. 2017). 3D printing can be said to have many potential applications in the maritime industry. Currently, 3D printing of spare parts is drawing the maximum attention. However, a future in which autonomous ships could identify a malfunction, print a spare part and replace it by a robotic tool without human intervention is possibly the future and not too hard to imagine. Since 3D printing is not a part of the mariner's education, even marine electrical engineering, our goal at the Faculty of Maritime Studies in Split was to introduce 3D printing technology into our curriculum, of two courses:

– New technologies of materials in electrical engineering, and

– New technologies in diagnostics and control.

In this paper, we present a class flow based on problem-based learning (Tan 2003). It is similar to project-based learning is implemented in (Chen et al. 2019). The paper is organized as follows: the second section presents methodology, the third section results, and conclusions are given in the fourth section.

Methodology

In order to facilitate turning this educational potential into reality, we acquired Velleman K8200 low-cost 3D printer kit (Figure 1) for our laboratory, since we had limited budget at our disposal. The printer was assembled during the year 2018 by a post-graduate student who graduated with a Masters degree from our institution (Maleš 2018).

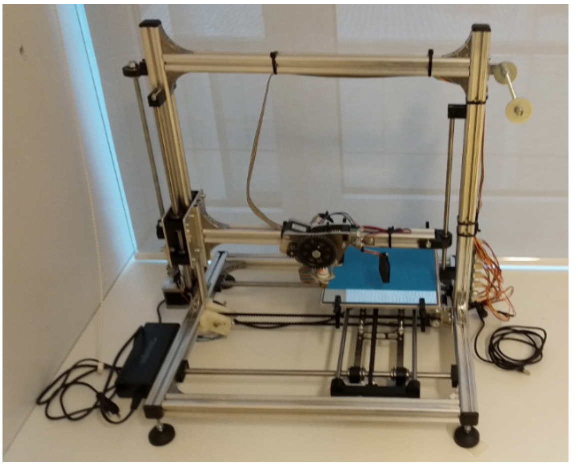

Figure 1. Velleman K8200 3D printer

While working with Velleman K8200 we were not fully satisfied with printing results.

Table 1. 3D printer class schedule

Class	Task
1	Introducing 3D printing technology, familiarizing students with Velleman K8200 3D printer
2	Discussing possible improvements, modelling improvements in CAD software
3	Modelling improvements in CAD software
4	Printing parts and assembly

Since it is a low-cost printer, it has some design flaws, which directly contributed to poor printing results. Nevertheless, we decided to introduce the 3D printer into our curriculum. Our plan was to introduce the marine engineering students to 3D printing technology, FDM technology and Repetier software, and an all-in-one software solution for 3D FDM printers provided with the 3D printer, in four 90-minute lectures spread across two weeks. The 3D printer class schedule is as seen in Table 1.

Educational methodology: class schedule

We can summarize a methodical sequence for conducting a practical lesson related to 3D modeling and 3D printing. It is shown in Table 2. Students are instructed to experiment with various parameters to get feeling about parameters' influence to the quality and speed of 3D printing.

Table 2. 3D printer class schedule

Class	Task	Duration
1	Introducing 3D printing technology, familiarizing students with Velleman K8200 3D printer	1h
2	Discussing possible improvements, modelling improvements in CAD software	1h
3	Modelling improvements in CAD software	8h
4	Printing parts and assembly	8h

Case study

During our first class, the students were familiarized with the Velleman K8200 3D printer and the issues the printer has. Since our funding was limited, we decided to resolve the problem of the Velleman K8200 3D printer. Students were engaged to discuss and to find the solution to the problems of the printer. Three issues were identified that need to be solved. The first issue was that the belt responsible for the X-axis movement of the print bed was too loose. The loose belt caused the printer bed to vibrate, resulting in inaccurate printing. Since the design of the K8200 3D printer did not allow for fine belt tensioning, we proposed a new design which would facilitate it. The second issue was the belt responsible for the Y-axis movement. This too had the same design flaw as the X-axis belt. A new design for the Y-axis belt tensioning mechanism was proposed. The third issue was that the Z-axis endstop screw responsible for endstop microswitch activation was too loose. While this issue did not cause any inaccuracies while printing, it was potentially a fatal design flaw capable of damaging the printer's extruder head and print bed. A new design of the screw holder was proposed which would eliminate the possibility of the screw not activating the endstop microswitch.

After discussing the proposed improvements, during the second class, students started designing the parts with CAD software. Since some students had experience with the CAD software from their previous classes, we divided them into groups, where more experienced students were encouraged to help their less experienced colleagues. We used free "123D Design software" provided by Autodesk[3]. After creating the 3D model in 123D Design (see Figure 2), students saved their 3D model as ".stl" file and were encouraged to continue their work on the models during the weekend. STL is a file format most commonly used for 3D printing. This format describes only the surface geometry of a 3D object without any representation of color, texture or other common model attributes (Chakravorty 2019). During the third class, their work was inspected and some iterations on the model design was proposed by lecturer. By the time third class ended all models were finished and STL files were subsequently imported to the Repetier software, where they got sliced by Slic3r software, a 3D slicing engine for 3D printers.

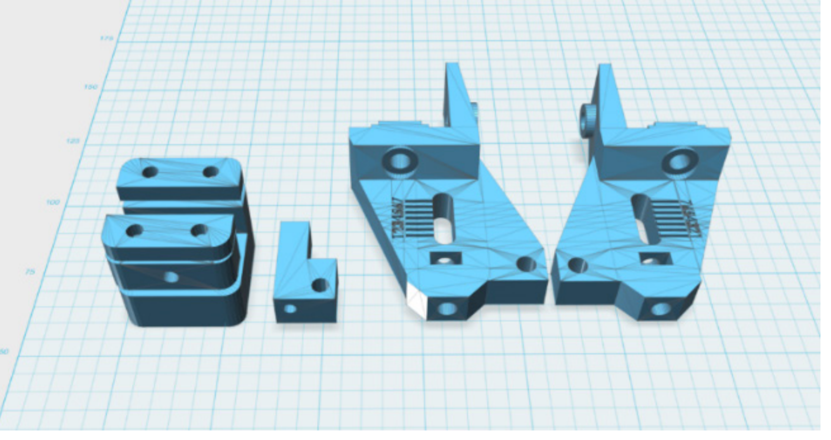

Figure 2. 3D models created by students

Results

In our fourth class, we finally started the 3D printing of the parts (see Figure 3 and Figure 4). We used transparent PLA filament with 2.8 mm diameter and in spite of optimized settings, the Velleman K8200 will need about eight hours to print all four modelled parts. Students were eager to see printer in work and when the printing process started, they kept watching the process until the end of class. The whole printing process took about eight hours so most of the prints were completed after the class finished.

The lecturer, without the student participation, completed the manufacture after the class, and mounted the parts on the 3D printer to resolve the identified problems. Students were eager to see what their parts looked like after 3D printing and, when they arrived day later, were happy to see them already mounted on the 3D printer (Figures 5, 6, 7). The improvements on the 3D printer made by the students during the class sessions proved to work as intended. Print bed shaking was significantly reduced and the loose endstop screw issue was fixed.

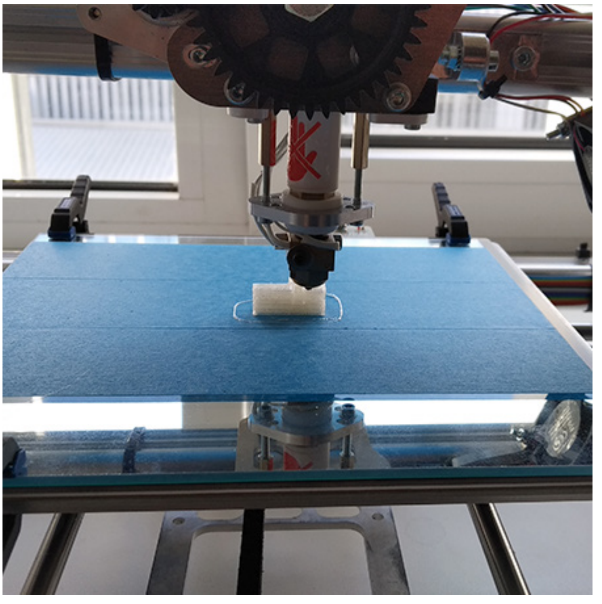

Figure 3. Printing the improved endstop screw holder

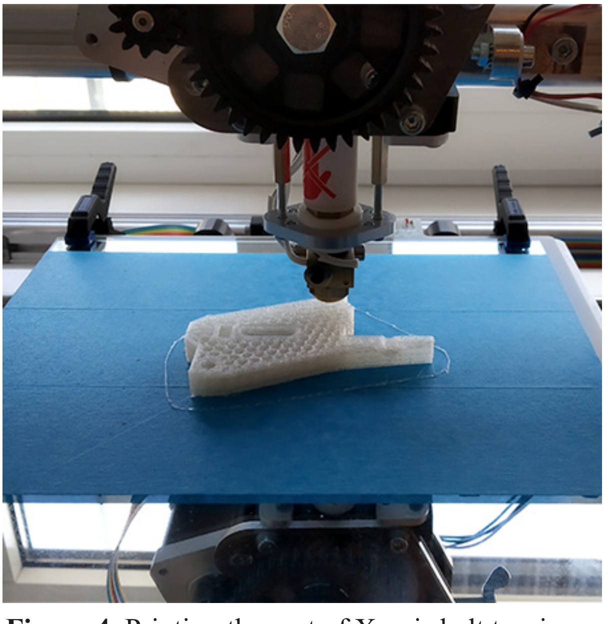

Figure 4. Printing the part of X-axis belt tensioner

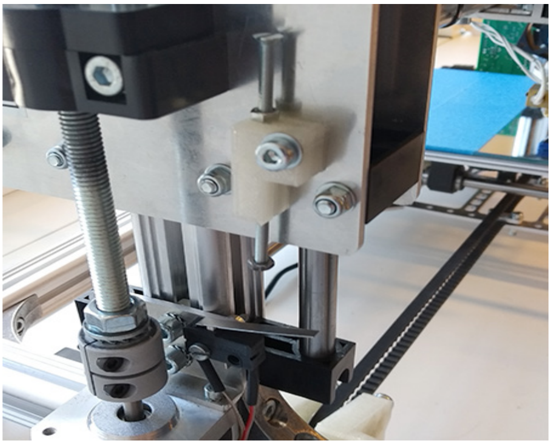

Figure 5. Mounted endstop screw holder

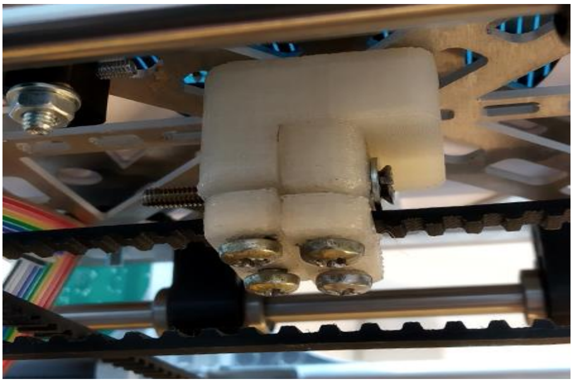

Figure 6. Mounted Y-axis belt tensioner

Figure 7. Mounted X-axis belt tensioner

Conclusions

We observed positive student response to this type of learning. The students were highly motivated and based on the feedback given by the students, they were highly motivated due to dealing with real problems and finding the solutions to those problems. Since some of the students were more experienced in using the CAD software, we divided them into groups to help their less experienced colleagues. 3D modelling proved to take most time, in future classes we will increase the class time for this activity. Process of 3D printing was most anticipated activity and students could not keep their eyes off the machine during the printing process. We concluded that students with no experience with 3D modelling can use 3D printing technology if they can obtain 3D models from other sources (internet).

The iterative process is convenient for classes because model sketches can be adapted and reprinted at any time, which is also an advantage in real life (spare part printing). We concluded that this is a good alternative to classic teaching approaches in education, since the work is rather of the “learning by doing” and problem-solving type. Introducing 3D printer into the curriculum revealed a new approach to research and education, with the idea of fabricating improved parts based on students’ good ideas.

We notice also some topics that would be of interest:

– it would be preferable to get feedback from shipping companies and ship owners on this classes,

– more classes are necessary to address design process of 3D printing.

NOTES

1. 3D printer Velleman K8200, 2013. http://www.k8200.eu (accessed July 22, 2019).
2. Pilot project: 3D Printing Marine Spares. https://www.portofrotterdam.com/sites/default/les/report-3d-printing-marine-spares.pdf (accessed July 22 2019).
3. Autodesk – Solutions 123 Design. https://www.autodesk.com/solutions/123d-apps (accessed July 22, 2019.).

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