THE CDIO APPROACH IN A FABLAB ACTIVITY FOR ENGINEERING EDUCATION PROMOTION

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ABSTRACT

The number of FabLabs has been steadily increasing over the last few years. Their main objectives are to sensitize its public on Science, Technology, Engineering, and Math (STEM) education through the digital manufacturing chain of an object and to allow the large public to make their own objects. Through, the increasing popularization of these advanced technologies, it becomes more difficult to establish the makers from the engineers.
The thinness of this distinction may have, in some cases, a negative impact on the promotion of engineering education. In actual engineering projects, a rigorous approach is usually followed such as the CDIO method. Meanwhile, the design rules pursued by the makers are not necessarily as systematic as the ones followed by the engineers.
In order to present this distinction to high school students, this paper illustrates the usage of a CDIO approach within the framework of a FabLab activity to promote engineering education. The proposed week-long activity concerns a personal loudspeaker construction using the resources and capabilities of a FabLab.
Furthermore, due to a precise number of turns in the windings, the manual construction of the speaker remains a considerably laborious task.
To solve this issue, the students are made responsible for proposing an innovative solution by applying a CDIO approach. This solution must lead to the design of a machine-tool manufacture dedicated to a loudspeaker production.

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1 INTRODUCTION

1.1 Emergence of Fablabs

The maker movement is currently a global growth phenomenon. It regroups different profiles of makers that collaborate through various social exchanges sometimes online and sometimes in specific spaces using technological resources to produce objects. Fig. 1 shows an order of magnitude of this growth as well as the increase of meeting places for those makers over ten years [1].

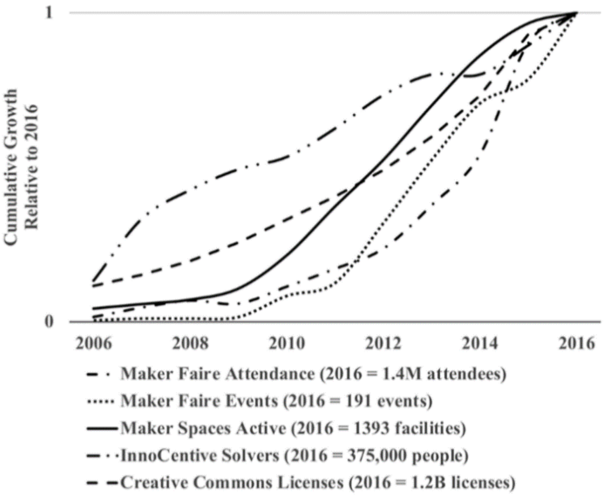

Fig. 1. Indicators of the global growth of the maker movement (2006–2016) [1]

This increase is due to the always growing financial accessibility of prototyping equipments, such as laser cutting, 3D printing or 3D scanning [2]. These low-cost tools are now accessible in different spaces such as hackerspaces, makerspaces and also FabLabs. The Fablabs are fabrication laboratories that guarantee to their members an access to different low-cost production machines. This initiative, created by the MIT physicist Nei Gershenfield in 2000, defines a charter with a minimum equipment to obtain the "FabLab" label. Nowadays, the FabLabs association has more than 1800 labelled fabrication sites. FabLabs constitutes also spaces for training and developing awareness regarding new technologies. Moreover, Fablabs are suitable for promoting STEM education through several activities [3]. Furthermore, makerspaces constitute a conducive environment for developing creative skills during engineering studies [4]. Unfortunately, the public within the FabLab is very heterogeneous which might cause a lack of understanding of engineering studies in general. Indeed, the FabLabs community is made up of individual makers who are “Do It Yourself (DIY) hobbyists”, artists, crafters and engineers [1]. In engineering studies promotion, it is essential to distinguish the maker and the engineer among the young public. The aim of this paper is to propose a FabLab activity that distinguishes these two profiles with the help of CDIO approach. The main objective of this ‘Conceive-Design-Implement-Operate’ (CDIO) approach is to make the connection between theory and practice [5]. Fig. 2 illustrates the distinction between the two profiles based on the CDIO approach.

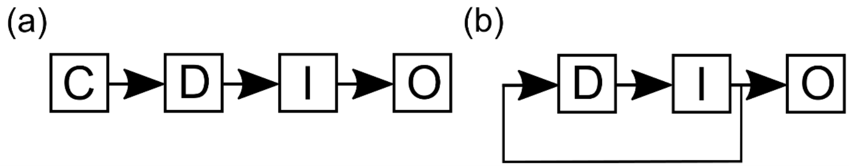

Fig. 2. Distinction between (a) engineer and (b) maker through the CDIO approach

Two points can be highlighted in order to help distinguishing these two profiles:

- **Conceive** is one of the most important steps in engineering. This consists in a comprehensive and precise study of the problem as well as the already existing solutions that provide a solution to each part of the problem.
- The **loop between Implement and Design** insists on the trial-and-error approach that highlights that the maker often obtains a solution by using an empirical approach.

This paper will try to highlight this phenomenon and its impact on the promotion of engineering studies through the feedback of the participants of the proposed FabLab activity.

2 DESCRIPTION OF THE ACTIVITY

2.1 General context

A week long activity is proposed to the students to illustrate the application of CDIO approach in different engineering domains and, especially, in Mechanics. This consists of an ex-nihilo loudspeaker construction using resources and capabilities of our FabLab.

The winding operation of the loudspeaker electromagnet remains an important step of the processing. It consists of winding a large number of turns of a copper wire in order to form a coil. The length of this copper wire can be up to 30 meters. Therefore, the winding step can rapidly become tediouswhile manually carried out.

The proposed activity is then to Conceive, Design, Implement and Operate a machine-tool manufacture dedicated to the production of winding coils until the realization of a loudspeaker.

2.2 Week-long activity organization

This week is actually organized in 4 days; each one being dedicated to one step of the CDIO methodology. During these days, the students have the opportunity to practice different disciplines of engineering, for example CAD modelling and also micro-controllers programming using Arduino boards. The students are grouped in teams of four people; each team designing its proper winding machine.

First day - Conceive

The first part of the morning is dedicated to a “icebreaker” activity allowing the participants to introduce themselves.

In the second part of the morning, the aims of the traineeship are presented and a dimensional study of the loudspeaker is carried out which allows us to determine the number of turns necessary to obtain a 8 Ohms resistance electromagnet winding (25m wire with approximately 400 turns). Each team should then manually performs the winding of the coil and measure the corresponding time this operation takes (approximately 10 min). The aim of this manipulation is to raise the students awareness about the interest of designing an automated machine-tool.

The afternoon is dedicated to the conceive part of the CDIO approach. Without knowing the material put at their disposal, each team performs a brainstorming that must lead to a technical solution. In the requirement specifications, it is imposed that their solution should allow a honeycomb winding methodology The students must research online for some usual existing mechanisms or potential solutions, especially for transforming a rotating motion into a periodic translational motion.

After a short reflection, all solutions are exposed between the different teams. Then, a general discussion takes place in order to examine the advantages and drawbacks of each solution. Merging all ideas leads to a unique technical solution that should be implemented by all teams.

Second day - Design

The morning of this day is devoted to CAD software initiation using SolidWorks. The students are expected to model the loudspeaker for which technical drawings are provided.

In the afternoon, the spare parts that allows the loudspeaker construction are provided to the teams. It contains an electrical motor, an Arduino kit, gear sets, threaded rods, screws, springs, bolts and nuts. Each team must then realize the technical assembly drawing of their winding machine. The important aspects that must be taken into account in the mechanical design are the gears coaxiality and the geometry of the wobble plate which oscillates and control the amplitude of the translational motion.

Each member of the team freely models with SolidWorks an element of the winding machine while respecting the requirement specifications. The assembly of the different parts of the system is then carried out to verify that all dimensional constraints are met (Fig. 3).

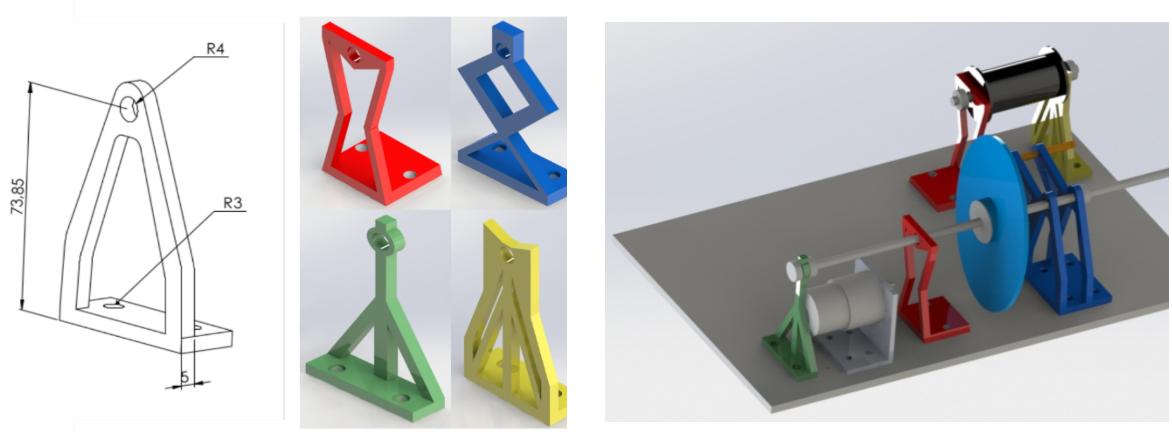

Fig. 3. different CAD models of the slide bearing frames and Solidworks assembly of the winding machine

Third day - Implement

It is dedicated to the manufacturing of the different constitutive elements of the winding machine. Some parts are made by 3D printing (such as the loudspeaker, the wobble plate or the thread guide) and others using laser cutting (such as the base plate and some slide bearing frames). We use laser cutting as much as possible since the corresponding manufacturing time is of the order of a few minutes while 3D printing can takes several hours.

During the 3D printing of the different parts, an introduction to Arduino programming is carried out. Student develop an Arduino program that controls the DC motor and measure the number of turns with an optical forked photoelectric sensor.

Last day - Operate

The morning is dedicated to the winding machine assembly and the production of one speaker coil. During the afternoon, the students implement a low voltage audio power amplifier using LM386 electronic component. At the end of the traineeship, each student can bring back home its own speaker and connect it to its smartphone with a jack plug to listen its favourite songs (Fig. 4).

Fig. 4. Assembly of the winding machine

3 RESULTS

It is always difficult to quantify the gains from an educational activity. The evaluation proposed in this paper is based on responses to a compulsory survey conducted after the traineeship. This survey has items common to all organized stages as well as items specific to the activity treated. Fig. 5 summarizes the responses of the students who participated to the stage described in this article. The students had three different choices for each evaluated point: *Done and I liked it*, *Not done but I would have liked it*, *Not done but without opinion*. It can be seen in this Figure that all of them constructed the machine tool and appreciated the realization of this general engineering project. The CDIO approach was an important part of this one. This self-assessment shows that the “Conceive” step has been well received by the students through the Project Making. The main objective of differentiating maker and engineer is thus achieved. In addition to this assessment, many learnings have been done, both technical and human. These learnings, that have not been measured, are:

- The development of the spatial vision using 3D software, plans, real manufactured objects and the link between them.
- The reinforcement of basic ideas in electricity and electronics that were not largely developed in Belgian secondary teaching.
- Taking technical constraints into account to produce an object but also to manufacture it.
- The teamworking qualities such as active listening, positive criticism, weight of arguments,

Over the last two years, 7 students out of 12 entered the Faculty of Engineering. Even if they were already interested in engineering studies, more than 50% of the participant decided to become an engineer to complete their maker profile.

To conclude, the activity proposed during this four-day internship seems to meet the objective of promoting engineering studies in the maker community but more broadly, softly develops useful skills of all participating students.

In perspective, new self-assessment indicators need to be defined, and this activity needs to be repeated to increase sampling to confirm the tendency.

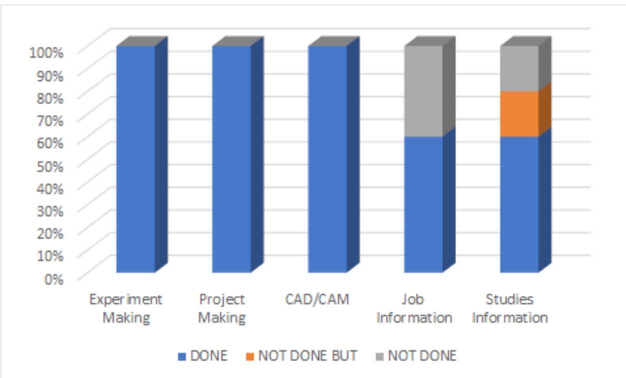

Fig. 5 Internship feedbacks

REFERENCES

[1] R. E. Browder, H. E. Aldrich, S. W. Bradley (2019), The emergence of the maker movement: Implications for entrepreneurship research, Journal of Business Venturing, Vol. 34, pp. 459-476.

[2] P. Blikstein, D. Krannich (2013), The Makers Movement and FabLabs in Education: Experiences, Technologies, and Research, Proceedings of the 12th international conference on interaction design and children, pp. 613-616

[3] K. Dreessen, S. Schepers (2019), Foregrounding backstage activities for engaging children in a FabLab for STEM education, International Journal of Child-Computer Interaction, Vol. 20, pp. 35-42

[4] J. L. Saorín, D. Melian-Díaz, A. Bonnet, C. C. Carrera, C. Meier, J. De La Torre-Cantero (2017), Makerspace teaching-learning environment to enhance creative competence in engineering students, Thinking Skills and Creativity, Vol. 23, pp. 188-198

[5] T. Cosgrove, J. O'Reilly (2019). THEORY, PRACTICE AND REFLEXIVITY: THE NEXT CHALLENGE FOR CDIO, Proceeding of the 15th International CDIO Conference at Aarhus University