DESK RESEARCH REPORT ON PEDAGOGIC APPROACHES FOR TEACHING 3D PRINTING

Part of the THREE-D-PRINT project

Funded by the Erasmus+ Programme of the European Union

https://www.3dprint-training.com/

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INTRODUCTION

When it comes to the application of 3D Printing in education, two important points are to be considered:

1. With the appearance of more affordable, low-cost 3D Printers, it has become easier to make use of its potential in education environments (Ford & Minshall, 2016).
2. The application of 3D printing in education not only facilitates learning and stimulates the development of hard skills, but it also increases student-teacher engagement in different subject matters (Assante, Cennamo & Placidi, 2020).

The connection of these two points is indicative that 3D printing technology prices will continue to decline as more businesses and more consumers start to adopt 3D printing technologies, and the technology becomes more developed due to market demands. Moreover, they evidence the importance of having educators who are able to work with 3D modelling and 3D printing so that this technology can be integrated and applied in the different fields of knowledge in the classrooms.

Following this premise, and because the THREE-D-PRINT project will create a training programme on 3D printing for trainers, this report aims to provide an overview of the pedagogic approaches that have been used for the teaching of 3D Printing for teachers.

In specific, this desk research focuses on investigating the delivery of 3D Printing courses in several projects and other initiatives concerning the teaching of 3D Printing. Important aspects of training delivery, such as the training approaches and impact of different online 3D Printing learning courses will be described, and a revision on reports of face-to-face workshops is also provided.

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PEDAGOGIC APPROACHES ON TEACHING 3D PRINTING

Because 3D printing is not (yet) an established field of science and technology (such as robotics or mechatronics), general research suggests that most 3D Printing courses available are offered in the form of MOOCs and (fee-based) short introductory courses and workshops.

E-learning platforms, such as Udemy and Coursera, offer a considerable amount of 3D Printing / Additive Manufacturing courses. It is also possible to find some major companies that sell and produce 3D printing technologies that also offer materials and (free) training for 3D printing.[1]

Several face-to-face initiatives have also been offered in universities or other education environments for teachers and adults. Some examples include:

- a workshop designed to stimulate a connection between 3D Printing and different History-related subjects in the University of Massachusetts Amherst (USA), in 2017;
- a workshop for teachers held in Michigan Technological University (USA), in 2015, that proposed teachers to assemble their own 3D Printer and take it back to their classroom for educational purposes; and
- The European Project "E-DESIGN" in which training on different Industry 4.0 related technologies was implemented.

To comprehend the way these well-reviewed introductory online courses and face-to-face initiatives are structured and delivered, an analysis regarding their pedagogic approach was conducted. Therefore, one free, well-rated course from each of the previously mentioned platforms, as well as the aforementioned face-to-face workshops, were explored and are described below.

[1] For example iMakr https://www.imakr.com/en/training-consulting-for-3d-printing/710-introduction-3d-printing-training.html; GoPrint3D https://www.goprint3d.co.uk/3d-printer-training/; RoboSavvy https://robosavvy.com/store/welcome-to-the-world-of-3d-printing-training-course.html; etc.

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"How to use and maintain a 3D Printer" online workshop (by Udemy)

Hundreds of 3D Printing / Additive Manufacturing courses (and other related topics) are available on this platform. However, only a few are free – most of the courses range from €20,00 to €160,00 per participant.

This research will focus on the "3D Printing Workshop. How to use and maintain a 3D Printer[2]" workshop. With a 4.1/5 average rating (in 625 total ratings, as of 13/05/2021), this workshop refers to a 2-hours long, free workshop for beginners. It is offered only in English. No requirements – other than enthusiasm and motivation for the topic – are needed, which demonstrates how accessible this technology can get.

The workshop is comprised of the following 5 different modules:

1. *What is 3D Printing*: the first module offers an overview of the 3D Printing technology and the workflow and software required to use a 3D Printer;
2. *Preparing, Slicing and Printing Your First 3D Model*: this segment demonstrates how to install a printer, edit your mode on a 3D modelling software and how to prepare a printer to be used;
3. *Filaments*: this section is dedicated to the types of filaments that are the most commonly used – ABS and PLA filaments;
4. *Fix My Print!*: this module focuses on basic maintenance routines that one can perform in order to ensure the 3D Printer is being taken care of;
5. *Printer Maintenance and Where to Next*: at last, this module demonstrates technical maintenance and how to replace and even print replacement parts.

Each module is divided into different topics. For every topic, there is a 1 – 10 minutes long video lecture where an instructor is presenting and explaining the topic at hand. Simultaneously, the instructor is working with a 3D Printer (figure 1) or modelling in the software Cura (figure 2). In the cases in which it is not as practical to show a certain piece or feature of the 3D printer, figures, photos and

[2] https://www.udemy.com/course/3d-printing-ultimate-workshop-and-full-step-by-step-guide/

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diagrams are displayed, as well as YouTube videos of a 3D Printer in action (figure 3).

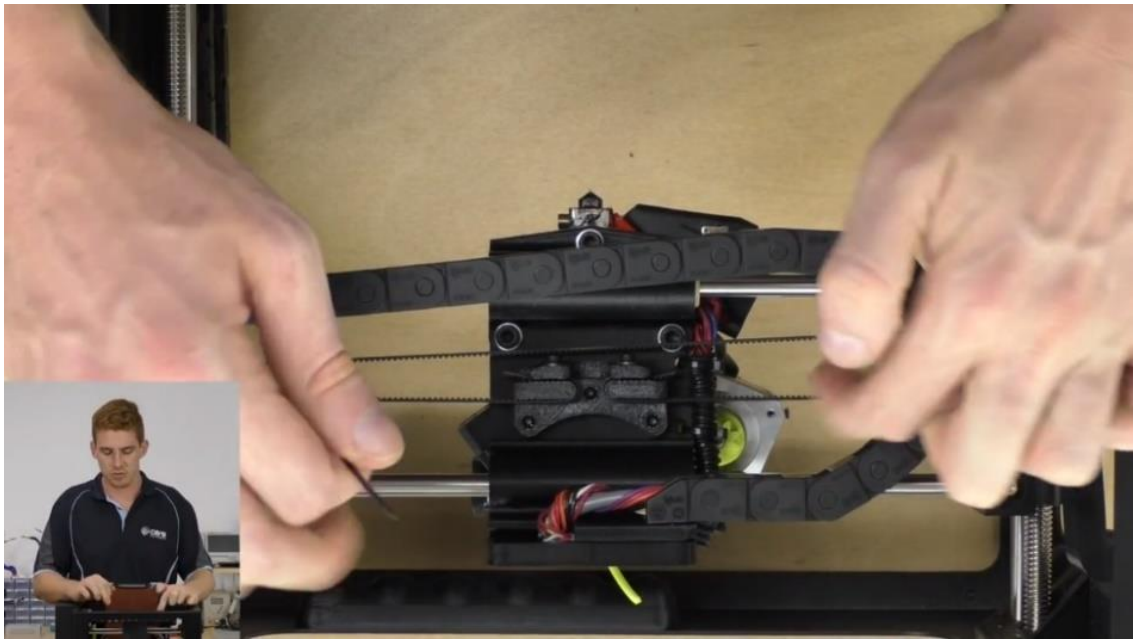

Figure 1 – Displaying of the components of a 3D Printer

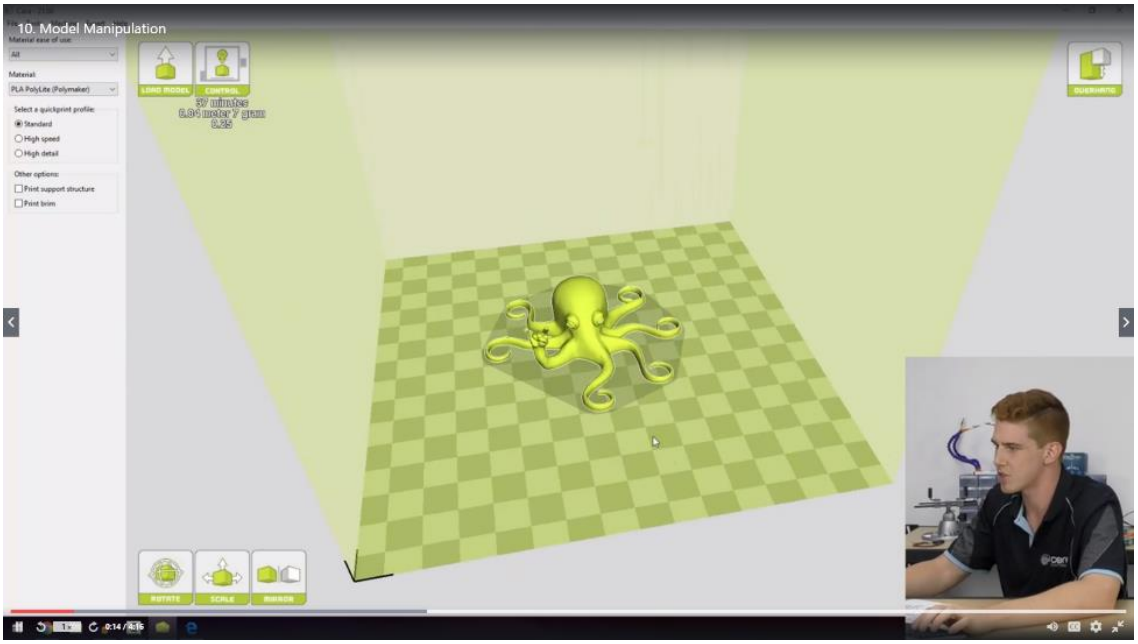

Figure 2 – 3D Modelling on Cura software

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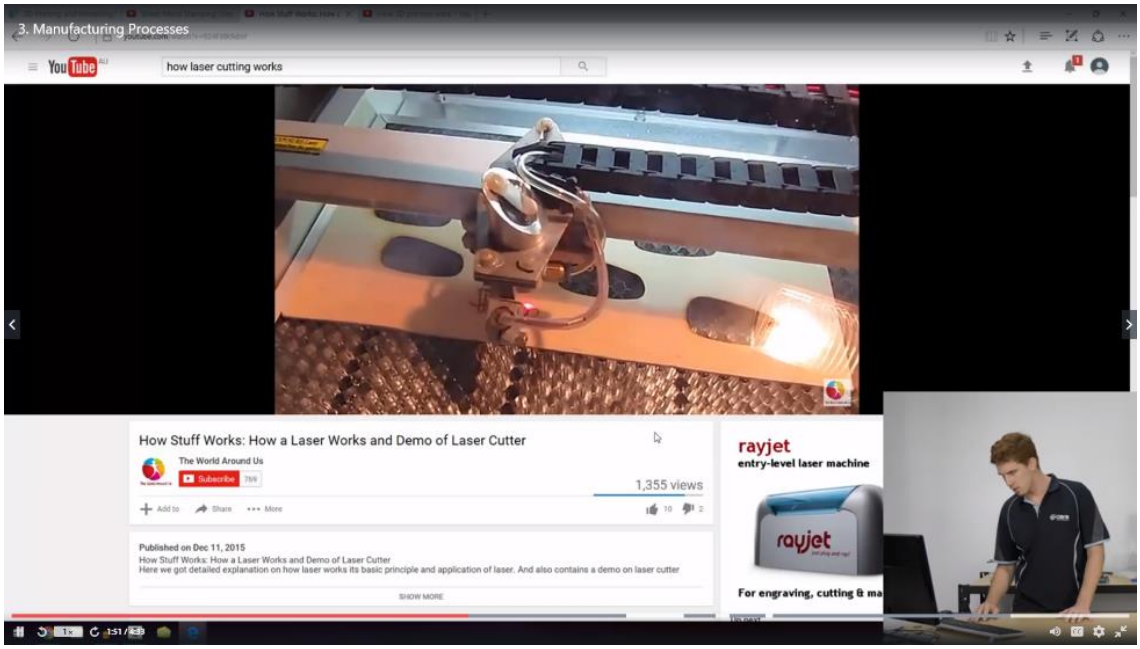

Figure 3 – Demonstration of a 3D Printer features using YouTube videos

"Welcome to 3D Printing Applications" online course (by Coursera)

Although still large, the list of courses offered in the Coursera platform is not as extensive as Udemy's.

The introductory course chosen for this research is "Welcome to 3D Printing Applications"[3]. The course is hosted and taught by 3D Printing experts from the University of Illinois (USA) and provides a comprehensive examination of all aspects of desktop 3D printing. This course has an average rating of 4.6/5 (as of 14/05/2021), and offers the possibility to obtain a certificate (even though one would need to pay for the course). Although the course is taught in English, it is possible to activate French, Portuguese (European), Russian or Spanish subtitles. It lasts, approximately, 20 hours.

Once one enrols in the course, a 4-week schedule (1 module/week) and a syllabus with the course's description, outline, goals and objectives and key concepts are made available. The four modules that belong to this course are:

[3] https://www.coursera.org/learn/3d-printing-applications/lecture/xYJax/welcome-to-3d-printing-applications

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1. *A Way of Making*: this module aims at giving an understanding of the history behind the creation of desktop 3D printers, the different types of desktop 3D printers, how they work, and what they are typically used for;
2. *On-Demand Manufacturing*: in this module, examples of how 3D printing enhances product customization, as well as the development of on-demand manufacturing, are discussed;
3. *3D Printing for Development and Education*: the role of 3D printing in education and the role it can play in the progress of underserved communities in both developing and developed countries is the main point of this module. STEM education is also one of the topics in module 3;
4. *From Ideas to Objects – A Design Thinking Approach*: the last module focuses on the design thinking process and its importance to create potential ideas and projects.

Each module has a section for reading materials (figure 4), and videos. At the end of each module, a small assignment, which is then peer-reviewed by another participant, is requested.

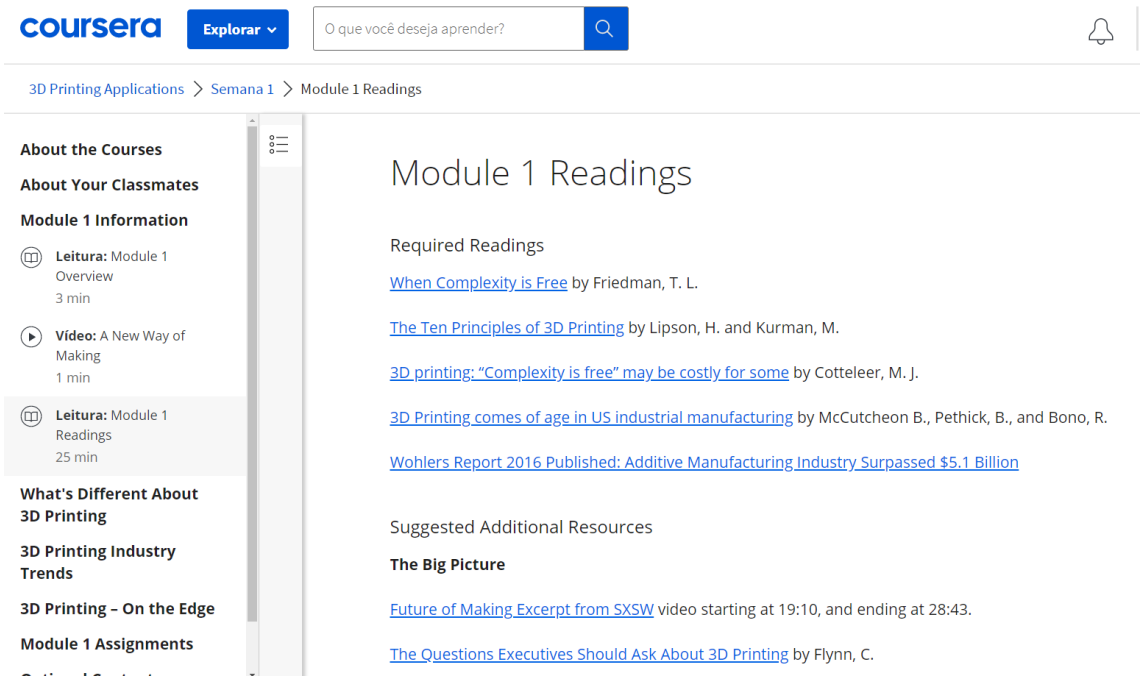

Figure 4 – Reading material available for Module 1

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The "3D Printing 4 Teaching & Learning" Project

This project refers to an exploratory study to examine the use of 3D technology by teachers and trainers in History-related classes from the University of Massachusetts Amherst (USA). The project, as described by Maloy, Trust, Kommers, Malinowski & LaRoche (2017), was designed and implemented with the aim to understand how current/future teachers, as well as public school students, would be able to connect the features of disruptive technology, such as 3D Printing, in their classroom.

In order to introduce the 3D Modelling and 3D Printing topic to the teachers, they took part in a two full-day workshop where they received an overview of this technology and began formulating ideas and activities for their curriculum projects in the classroom. This introductory process was fundamental because it allowed teachers to experience "the design thinking and creation processes that are fundamental components of 3D printing and modeling" (Maloy et al., 2017).

After the 2-day workshop, teachers finally implemented their acquired knowledge during their classes with students. Even though teachers and students were initially unsure on how to connect both the 3D Printing and History-related subjects, interesting curriculum projects that connected 3D printing to the subject's learning objectives were developed. Four teachers designed lesson plans to implement with their students and brainstormed with them on what methodology they could follow to complete the tasks.

The approach that was generally taken consisted of traditional research about the topic and brainstorming ideas to represent them using the 3D Printing technology. Because they followed a DIY (*Do It Yourself*) methodology, students 3D modelled any object using the online 3D modelling programme Tinkercad. It became clear that, while some students sketched their designs in Tinkercad right away, in general, students who first sketched their designs on paper before moving to Tinkercad were able to build them more efficiently.

The four projects that were developed were linked with the school curricula as follows:

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Subject	Curriculum topic	How the project was developed
World Geography	The access to and use of oil and water in Central and South Asia.	Students from this project created a 3D model related to water conservation with the aim to use water more efficiently and less wastefully.
U.S. History	Interactions between native people and European settlers in Colonial America; and Events leading to the American Revolution.	Students designed different native American dwellings (such as teepees and igloos) as a way to have students explore Native American heritage; and For the second topic, students decided to make a board game, so they designed the game pieces, as well as the cardboard, focusing on key events that led to the American Revolution of 1775 – 1783.
American Government & Civics	The use of memorials and memory in building civic understandings	This project focused on hidden histories and missing monuments that shaped US culture. Hence, students designed monuments dedicated to key figures. Moreover, they created a plaque with a brief description of the person to whom the monument was dedicated explaining the reason.

Insights collected from this group of teachers suggest that designing and printing 3D objects related to historical topics "can create a framework for active, engaged learning in the history and social studies classroom" (Maloy et al., 2017). Students were also able to benefit from interacting with this technology since they were able to create a visual representation of the knowledge they researched, thereby enhancing their engagement with the topic and experiencing an alternative way to learn concepts.

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The "RepRap 3D Printer" workshop

Another initiative comes from the example provided by Schelly, Anzalone, Wijnen & Pearce (2015): it concerns a 3-day training workshop that was conducted in the Michigan Technological University (USA), and whose participants – 22 in total – were middle school and high school teachers from a wide range of disciplines included in the STEM fields.

This workshop aimed at investigating (i) how easily can non-3D Printing-experts assemble a 3D Printer, (ii) the degree of intuition to which the educators would be able to develop a 3D printing project by themselves, and (iii) how enlightened they would be after the workshop regarding the potential of linking 3D printing aspects with their field of knowledge in the classroom. In order to provide this feedback, teachers built a RepRap 3D Printer[4] that could then be taken to their classroom for educational purposes.

As an introduction to the workshop, the workspace was shown to the educators and the tools were distributed. Moreover, best practices on what to do and not to do were presented. Afterwards, educators were grouped in pairs of two and were given wiki-based digital instructions and visual representations on how to proceed. Although it concerned a technology that they were not familiar with, by the end of the workshop, all educators were able to successfully assemble a 3D Printer, as well as print objects.

A post-workshop questionnaire concluded that, through this experience, educators have recognized the potential and easiness of integrating 3D printing technologies in STEM education, career and technical education, as well as other class subjects. Teachers were invited to keep the 3D Printer and take it to the classroom for educational purposes.

[4] RepRap (self-replicating rapid prototyper) 3D printers are open-source 3D printer designs available for anyone to build. Structural components from RepRap are built themselves by another RepRap 3D Printer.

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European Project "E-DESIGN"

Under the EU-funded project "E-DESIGN – European Digital Education for Social Inclusion and Global Neighbourhood"[5], CEPROF and Citizens in Power are developing training material regarding, amongst others, 3D Modelling and 3D Printing.

While the training sessions are directed to disadvantaged groups, there are teachers and trainers who are taking part as volunteers so that they can apply the knowledge acquired in class and replicate these sessions in the future. Training sessions exclusively for teachers/trainers have also been conducted. (figure 5).

Figure 5 – Training session with trainers at Landgraf-Ludwigs-Gymnasium, in Giessen (Germany). Photo by: ZAUG gGmbH

The training sessions are 36-hours long (implemented over 1 to 3 months) and are conducted under the DIY principle: participants are stimulated to look for solutions by themselves for the problems that are proposed, hence promoting

[5] For more information about the project visit https://www.e-designproject.eu/; Project reference: 604451-EPP-1-2018-1-DE-EPPKA3-IPI-SOC-IN

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hands-on experimentation and giving room to fail and make mistakes – a normal phase of any learning process.

Regarding the training material from 3D Printing, it consists of a Trainer Handout with a general description, learning objectives, preparatory steps for the trainer, tips on how to organize a learning activity and other additional information; there are also different task sheets with activities for participants to try – for instance, testing and calibrating a 3D Printer, changing the filament, preheating and cooling, and printing objects.

European Project "ROTENA"

Another European project in which the potential of 3D Printing was explored was "ROTENA: Robotics – Training for the New Age"[6], in which EU15 Limited and CEPROF were a part of.

Partners from ROTENA developed an introductory training programme, incorporating a combination of robotics competition activities and curriculum, designed to help teachers to teach programming skills to young people to enable them to gain knowledge and experience of these new technologies. Among the topics, a module addressing the use and application of 3D printing (which can be used to build the component parts of robots) was created.

The 3D printing module from ROTENA – rich in visual representations to support any given instruction and examples – focused on providing the fundamentals about working with a 3D Printer. Therefore, amongst others, there were sections dedicated to displaying the most used types of 3D Printers, adding a printer to Cura, creating and importing STL files, types of filaments to be used, safety rules to consider while 3D Printing and how to successfully 3D print.

In a pilot-testing aimed at evaluating the "ease of use" of the training curricula), most of the evaluators (77 in total) gave positive feedback, even complimenting how clear and intuitive the course was structured[7].

[6] For more information about the project visit https://www.rotena.co.uk; Project reference: 2016-1-UK01-KA202-024437
[7] ROTENA's evaluation of the pilot-testing report: https://www.rotena.co.uk/trainingprogram.html

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KEY FINDINGS AND CONCLUSION

The courses that were analysed allowed us to discern some of the practices that enable a 3D Printing course to be successful – whether it is an online or a face-to-face one. Because 3D printing is not (yet) an established field of science and technology (such as robotics or mechatronics), general research suggests that 3D Printing courses are not taught in the form of courses by most vocational and higher education institutions (except for some classes on manufacturing technologies), but rather offered in the form of MOOCs and short introductory courses, although most of these are paid or require a subscription fee. Some face-to-face workshops have also been offered – however, they are generally implemented for the teachers/trainers of the school/university in which the offer is implemented.

Generally, 3D Printing courses start with an overview of the concept in order to have the participant understand what can be achieved with this technology and its applicability in the real world. Similarly, the *do's* and *don'ts* when working with a 3D Printer are also useful to learn. Online courses tend to often rely on visual representations and videos to explain concepts, thereby making it more dynamic and smoother for people who are not familiar with the technical vocabulary and/or software to follow the courses; as for the face-to-face courses, they focus on a very practical approach rather than just having a trainer show how the 3D Printer works. When replicating such an approach in the classroom, having students engage first-hand with such technology and having them make their own visual representations, an increase of engagement with the subjects is ensured. Having students design their objects using 3D software (such as Tinkercad or Cura) promotes, likewise, the design thinking and creativity process that are imperative in 3D printing and modelling activities.

It is well-established that 3D printing fits neatly with the current trend for STEAM education (Science, technology, engineering, arts, and mathematics). By enabling students to engage with STEAM concepts from a young age, STEAM education aims to adopt a new learning approach that goes beyond the ability to remember facts and procedures. STEAM encourages people to use their

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creativity, critical thinking, knowledge, and skills in real-world situations, which is why teachers/trainers need more 3D Printing opportunities to learn with technology and hands-on experiences so that they can acquire the expertise to be used in classrooms (Sullivan & McCartney, 2017).

3D Printing is instilling a disruptive innovation in several sectors, including education. With the introduction of more courses offered by adult education institutions and increased awareness that this technology exists, the education sector will undoubtedly begin to reap the many benefits of 3D printing and inspire artists, architects, and engineers in the years to come.

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REFERENCES

Assante, D., Cennamo, G. & Placidi, L. (2020). 3D Printing in Education: an European perspective. 2020 IEEE Global Engineering Education Conference (EDUCON). DOI: 10.1109/EDUCON45650.2020.9125311.

Ford, S. & Minshall, T. (2018). Invited review article: Where and how 3D printing is used in teaching and education.

Maloy, R., Trust, T., Kommers, S., Malinowski, A., LaRoche, I. (2017). 3D Modeling and Printing in History/Social Studies Classrooms: Initial Lessons and Insights, Contemp. Issues Technol. Teach. Educ. 17 (2017) 229– 249.

Schelly, C., Anzalone, G. C., Wijnen, B., & Pearce, J. M. (2015). Open-source 3-D printing technologies for education: Bringing additive manufacturing to the classroom. *Journal of Visual Languages & Computing, 28*, 226-237.

Sullivan, P. & McCartney, H. (2017). Integrating 3D printing into an early childhood teacher preparation course: Reflections on practice.

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