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EXPERIENCES IN 3D PRINTING APPLIED IN EDUCATION

ISKUSTVA U PRIMENI 3D ŠTAMPE U OBRAZOVANJU

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Abstract

3D printing is a technology at the core of Additive Manufacturing. Applications of 3D printing are numerous: in mechanical engineering - for rapid prototyping or additive manufacturing of finished products; in architecture, civil engineering and masonry - to make scaled physical models; in dentistry - to produce dental implants; in medicine - to manufacture pharmaceuticals and its packaging, to produce implants or prosthetic devices, or even artificial tissues and organs; in art and design - for 3D printing of clothing, objects of art, or home appliances and aesthetic utensils, and so on. Wherever there is an application of 3D printing in some area, there is, or can be, an implementation of 3D printing in education.

Izvod

3D štampanje je jezgro aditivnih postupaka proizvodnje (engl.. Additive Manufacturing). Primene 3D štampanja su mnogobrojne: u mašinstvu - za brzu izradu prototipova i gotovih proizvoda; u arhitekturi, građevinarstvu i zgradarstvu - za izradu srazmerno umanjenih fizičkih modela; u stomatologiji - za izradu zubnih implantata; u medicini - za izradu medikamenata i njihove ambalaže, za izradu implantata ili protetičkih pomagala i uređaja, ili čak i veštačkih tkiva i organa; u umetnosti i dizajnu - za 3D štampanje odeće, umetničkih predmeta ili uređaja za domaćinstvo i estetski oblikovanih pomagala i drugog. Gde god postoji primena 3D štampanja u nekoj oblasti, tu jeste ili može biti i primena 3D štampanja u obrazovanju.

INTRODUCTION

Rapid development of 3D printing technology has introduced new solutions (some new problems arose too) in the industry, as well as in areas of applied science (including mechanical engineering, aerospace, robotics, electrical engineering, etc.). As new opportunities are emerging, the need for improvement is rising to achieve desired goals. There is a variety of important uses for applying the 3D printing in education, in primary and secondary schools, as well as in universities, libraries and technical colleges /1-2/.

Application of 3D printing in education has several goals /2-3/: teaching students and educators about 3D printing, supporting technology in teaching, making artefacts that aid learning, creating assistive technologies, and supporting the outreach activities. 3D printing technologies contribute to the improved learning, skills development, and increased student and teacher engagement with the teaching subject /1/. Five major benefits of 3D printing in education are /1/: it creates excitement, complements the curriculum, provides knowledge previously unavailable, opens new possibilities for learning, promoting problem-solving skills. Application of 3D printing in education is based on two questions /2-3/: Where is it used and how is it used in educational system? 3D printing technologies enable practical, hands-on knowledge for the understanding of scientific and engineering concepts, /4/. Modern educational institutions need robust 3D printers built for classroom demands, which are relatively easy to assemble, affordable and user-friendly, for fabricating 3D models using different materials. Additive manufacturing provides many opportunities to aid visual and practical learning over various areas of the science and engineering, /1-6/.

Undergraduate mechanical engineering courses can be radically transformed and can gain enhanced pedagogies when utilizing 3D printing /6/. To give an example of the application of 3D printing in education the 3D printer based on FDM (Fused Deposition Material) technology is used in the Academy of Applied Technical Studies Belgrade, /7-9/. 3D printer supports .STL files which are obtained in any 3D modelling program. In this application SolidWorks is used as a modelling program.

APPLICATION OF 3D PRINTING IN EDUCATION

There are various types of educational institutions where 3D printing can be applied /1, 10-11/: schools, universities, colleges, libraries, museums, and in special education.

Schools

Usage of 3D printer in schools covers all aspects and levels: Primary school, middle and high school. Introduction to 3D printing to students in schools is an excellent way to

present them how technology is rapidly improving and to learn the basics of 3D printing, /1/.

Since students in schools are children from 6-7 to 17-18 years old, their level of creativity and imagination is higher, teaching and allowing the students to 3D print by themselves can also boost their learning capabilities. Best usage of creativity is when students apply the 3D print on objects they would use for learning in different subjects.

Universities

At universities - almost all areas of science and engineering can be better understood via 3D printed models. Also 3D printers at universities have the greatest applicability in and adaptation to the use in engineering and applied science.

The best way to understand science is through the feel and hands-on the 3D printed objects - based on the subject 3D printed objects will differ. It will encourage students to learn through practical methods since only theory can lead students to boredom and losing the will for learning. Their only goal then will be to only read the theory and to memorize the text, /1/.

The best way to enhance the time spent in the classroom is via supported learning where 3D printed objects are created to aid students and teachers in the lab or classroom, where models are produced for visual learning. For enhanced practical learning test models are created where students can use 3D printed objects to actually perform experiments and gain results throughout their studies. 3D-printed components are often used as test models for specific scientific experiments, /1/.

One of the ways to control the 3D printer is by making a CAD model. This method is like dual-aimed learning where students first need to learn how to make CAD models in various software tools and then to apply the model created to the 3D printer in order to make the physical object or final product.

Libraries

Libraries provide opportunities for collaboration and knowledge exchange between library users, librarians, and educators. There are school libraries, university libraries, public libraries, etc., all of them can make use of 3D printer and provide one.

Most libraries have public access which means everyone can come to see or learn about 3D printing or try to print their own objects for later use. The advantage for library visitors is that most libraries provide use of 3D printer free of charge.

The libraries also provide service for people who do not know or do not want to use 3D printer by themselves, librarians, or special staff, who are in charge for 3D printer can produce the desired models for their customers.

Museums

Museums can provide copies of artworks to be touched and felt by the visually impaired visitors. At the Museo del Prado in Madrid, six paintings representing different pictorial genres have been 3D printed and made available to be touched by everyone. This exhibition was named 'Touching the Prado' and touching art pieces is encouraged rather than prohibited, /10-11/.

Assistive technologies for special education

In special education 3D printing is used as one of assistive technologies - for those with visual, motoric and cognitive impairments. The usage is mostly based on creation of custom-designed devices and adaptive educational aids while also enabling student engagement.

Students are also encouraged to create their own 3D models as well as open-source repositories or internet sites; both are used to modify existing 3D models. Encouraging teamwork and building confidence is the best way to help and complete the challenges that students with special needs have.

3D PRINTING BY SUBJECT OF STUDY

Wherever there is an application of 3D printing in some area, there is or can be an implementation of the same (3D printing) in education in that area. There are several ways how 3D printing is applied in subjects:

Math – helping students explore geometrical shapes and bodies through touch and also understanding of rotational symmetry that is shown on the paper most of the time.

History – creating historical artefacts or sculptures for students to experience the past instead just looking at the images in their books. Also it will help students to experience ancient traditions and cultures.

Geography – creating a 3D terrain for students to feel and examine it more detailed with usage of 2D maps, 3D printing a volcano for studying its layers and functions, 3D printing the effects of erosion or corrosion of rivers.

Engineering is where 3D printing is the most widely used in education. Students should understand and learn more details about 3D printer hardware, software, and its functions. As for the different subjects in engineering, another application is the printing of parts and later combining them in assemblies which can be useful as a practical solution for specific assignments.

Science – most students find it hard to understand the concept of science, 3D printing can increase their interests in science. For example in biology, creating replicas of organs or DNA structure to understand various functions. In chemistry 3D printing models of an atom, molecules, and molecular bonds.

Palaeontology – CT scans of the finds can be made, like in the case of mastodon bone, and then the 3D model can be printed, based on the scans; further examination can be made on 3D printed models, without the risk of damaging the original artefact.

Art – creating different types of designs, 3D printing tools that can help in their artistic creations, students can design their own objects that need to be drawn such as sculptures and vases. 3D printing in art can help students in observing and responding to their memory or imagination and present it through 3D printed objects. Established authors are already exploiting and utilising 3D printing in their artistic expression, like Iris Van Herpen, /12/, or Anouk Wipprecht, /13-14/.

3D PRINTING IMPLEMENTATION IN TEACHING

This section describes four ways how 3D printing is used in education: teaching students about 3D printing, teaching educators about 3D printing, 3D printing during teaching and assistive technologies.

In the first instance students need to learn about the 3D printer through active and passive methods. It is required to teach students about the 3D printer itself, how does it work, what are its hardware and software. The active method of learning is to give students the opportunity to try and 3D print their own desirable objects with previously shown demonstration on how to print. The passive method requires students to listen to theoretical presentations on 3D printers. Both combination of passive and active method of learning will bring great results, depending on students' interests. Students should be introduced to different 3D printing technologies such as FDM, SLA, SLS/SLM and variety of scanning techniques. The most ideal 3D printing course would consist of introducing to 3D printing, CAD modelling, post processing, safety, and different applications.

Teaching educators about 3D printing can become a challenge since 3D printing covers multiple science branches and art, for students that will not be a problem since they are focused on education that their institute provides. Teaching the educators about 3D printing is based on understanding the hardware and software of a 3D printer and how to control a 3D printer. Educators will later combine their knowledge (science, art, design) with newly learned 3D printing techniques to realise their classes. Problems appear when science and art collide, depending on the educator's attitude and understanding, science educators cannot understand the design thinking, and art educators cannot understand engineering habits. Another problem appears where educators do not receive sufficient guidance on the maintenance of 3D printers where the institute needs to hire trained people for 3D printer maintenance.

Using 3D printing during teaching is focused on where students are using 3D printer to learn about other subjects. Direct support in creating experimental models for mechanical and structural engineering, developing computational thinking, support teaching in biology, chemistry and mathematics. 3D printing in design introduces students to product processes as well in architectural design. It is used in design projects such as robotics, home appliances, car models and art. In engineering, 3D printing has been proven most useful for creating low-cost educational parts where modifications can be easily made.

Assistive technologies are being used in special education for students with visual, motoric, and cognitive impairments. For example, for visually impaired students, 3D printing is used to create a range of tactile artefacts like graphic assisting for programming, mathematics, geosciences maps, and history books.

PROBLEMS THAT CAN OCCUR IN 3D PRINTING PRACTICE

All mentioned educational institutions should consider having a 3D printer that shall pay off, not just financially, but also to keep in mind that there are students and educators interested in 3D printing.

If students and educators agree in installing a 3D printer in their institute, the new problem that appears is the hardware and software that will be used. Everything depends on the branch of science where that 3D printer is to be used and also the time spent creating 3D objects. The next problem is system complexity, because educators should be the first to understand and learn how to use a 3D printer, its parts, and the software the 3D printer supports.

With everything set up, system malfunction may occur due to wrongly manufactured parts, program errors, and poor maintenance.

Utilisation can also be the part of system malfunction, depending on how educators and students use and behave with the 3D printer. Using a 3D printer with aggression or poor handling can result in broken hardware. Students can struggle with 3D printing without the experience in 3D modelling, where they need additional educator support.

CLASSROOM TIPS

For successful 3D printing applications, every classroom has a few tips or rules that should be followed:

1. Keep a log: it is advised to make a log or a list of activities that are performed by the 3D printer. For example how many students use the 3D printer, for how long, how much material is used, …
2. Set criteria: students like to produce their 3D objects with large dimensions, which can affect time for printing and also usage of material, it is advised for students to design models with smaller dimensions.
3. Failed prints: everyone who works makes mistakes, but mistakes are often present when people are learning, not every object will be 3D printed perfectly.
4. Group work: the best way to learn is in group work, it does not just teach students about the certain subject but also how to help each other. Group work means better results.
5. Hands-on: educators must look out for their students, how they use and behave with the 3D printer, so they do not damage it.
6. Open for changes: both students and educators should consider changes offered from both sides so the classes can be upgraded.

3D PRINTER IN THE ACADEMY OF APPLIED TECHNICAL STUDIES BELGRADE

The 3D printer in the Academy of Applied Technical Studies Belgrade is based on FDM (Fused Deposition Material) technology. It uses .STL files modelled in any program for 3D modelling (SolidWorks, Pro-Engineer, Catia, Inventor, etc.). It can also use 3D-derived files by scanning. It is able to work with PLA (polylactic acid) and ABS (acrylonitrile butadiene styrene) wire 3 mm thick. The outlet nozzle that melts the wire is 0.5 mm diameter. For PLA wire, the nozzle is heated to about 190 °C, while for ABS it is heated to about 240 °C. Glass panel (240 mm × 300 mm) is heated to 65-70 °C. Certain parts of the 3D printer can be made on the 3D printer itself, so that self-construction is practically

possible. Axis control is performed via stepper motors and threaded spindles. The board that controls the 3D printer is the Arduino Mega 2560 (Mega ADK).

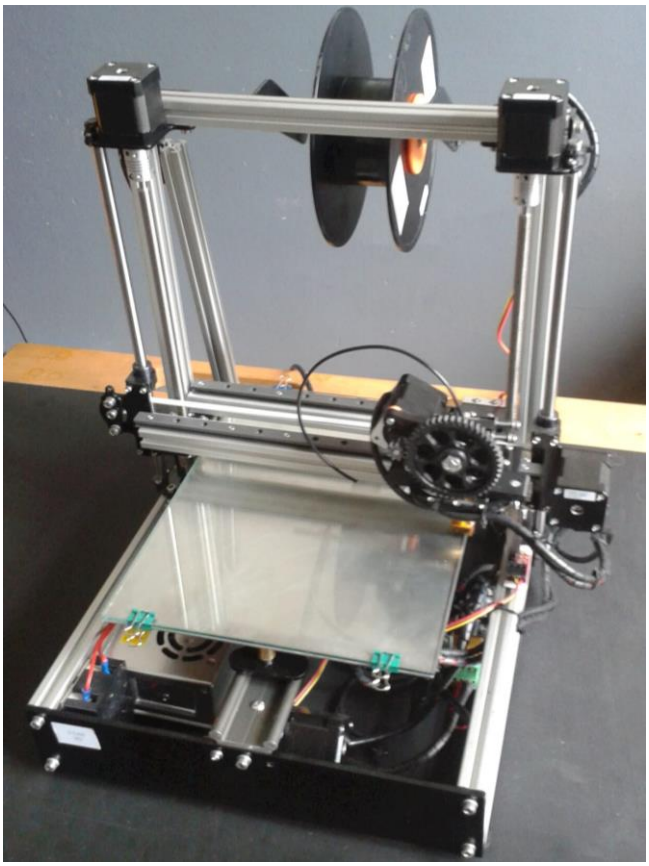

Figure 1. 3D printer at the Department for Computer-Machine Engineering, Academy of Applied Technical Studies Belgrade.

Students are introduced to the technical characteristics of the 3D printer and the software used for control. To fully experience 3D printing in mechanical engineering, students receive finished parts and measuring instruments such as callipers and micrometres (or micrometre screw gauges). Educators explain to students how measuring instruments are used, and later students measure finished parts and use the modelling software SolidWorks to draw the part, which educators also explain. After the modelling file is saved with extension STL it can be imported to the PC which is connected to the 3D printer. Then students are taught how to use 3D printing software to manufacture their drawn 3D model. Here students are not only introduced to the 3D printer itself but also how to use measuring instruments and how to use SolidWorks. Manufactured mechanical parts can be used as examples for the subject of mechanical members, or for testing material durability in the engineering materials subject, /15/.

CONCLUSION

3D printing in education has proven to be one of the best ways to motivate and encourage students to learn the fast and an effective way. Many students do not like studying certain subjects and they only try to memorize the text written in textbooks so they could obtain high grades. That

Figure 2. Example of 3D printed parts during introduction class.

is not the viable goal of learning. The intended goal of learning is to develop critical thinking and to understand the most important concepts of lectures and every word that is written or said during class, and also to make every class interesting. 3D printing provides better learning conditions and an environment where students can actually see or feel objects that they are studying, depending on the subject of study. The best way is to combine theoretical and practical classes together so when educators explain something in theory, they can also show their students what they are teaching about through 3D printed objects in practise. When students perceive their classes to be interesting, engaging, entertaining and meaningful, they may gain more will to study that subject or even to do their own research based on certain topics. Allowing students to try 3D printing by themselves also enhances their practical skills, way of thinking and bringing solutions, and also encourages working in a team for even better results.

There is a growing number of 3D printing organisations that are providing educational support. The best adoption is in universities and higher education institutions with courses in engineering and design.

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ESIS ACTIVITIES

CALENDAR OF EVENTS IN 2022

June 25-26, 2022	7th Summer School on 'Fracture Mechanics and Structural Integrity'	Funchal, Madeira, Portugal	link
June 27-July 01, 2022	23rd European Conference on Fracture - ECF23 (Symposiums TC2, TC3, TC14, TC15)	Funchal, Madeira, Portugal	link
September 12-14, 2022	TC3 Symposium – 'Structural Integrity and Life Extension' at the International Conference on Renewable Energies and Ocean Technologies (REOTech 2022)	Porto, Portugal	link
September 12-14, 2022	TC2 meeting – 10th International Conference on Materials Structure & Micromechanics of Fracture	Brno, Czech Republic	link
October 2-4, 2022	2nd International Symposium on Risk Analysis and Safety of Complex Structures and Components (IRAS22)	Belgrade, Serbia	link
September 17-21, 2023	9th International Conference on Fracture of Polymers, Composites and Adhesives (TC4)	Les Diablerets, Switzerland	

ESIS Newsletter link
https://www.structuralintegrity.eu/Newsletter/ESIS_NEWS_March_2022/index.html