

3D Printing in Education: A Primer

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ABSTRACT

The 3D printer uses raw material combination and builds an object one layer at a time. Advances in new material advances are keeping 3D printing at the forefront of innovation across many industries. Education is now be identified as a key target market within the 3D printing industry because 3D printing engages students more profoundly to learn lessons It is currently in the process of revolutionizing the manufacturing industry worldwide. The concept of 3D printing is simple, tried, and tested education tool for teachers. Today the importance of including 3D printing in professional degrees and in schools is a fact. 3D printing should be added to the curriculum in all academic institutions because it prepares the youths for the future. It presents opportunities to learn and use the same cutting-edge tools as professionals in the industry. This paper provides an overview of 3D printing in education.

KEYWORDS: 3D printing, additive manufacturing, modeling, education

INTRODUCTION

Education is one of the most precious gifts we can offer our future generation. It continues to be a major concern for many Americans. This is evident by the unparallel amount of money spent by the US on education. Educators have a monumental task before them and face many challenges. Skills sought after in the job market evolve faster than their curriculums. Educators need to determine which technology is the best for their curriculum. Educational technology is the means of accelerating progress, delivering on the future of design potential, and making the earth a better learning environment.

WHAT IS 3D PRINTING?

3D printing (also known as additive manufacturing (AM) or rapid prototyping (RP)) was invented in the early 1980s by Charles Hull, who is regarded as the father of 3D printing. Since then it has been used in manufacturing, automotive, electronics, aviation, aerospace, aeronautics, engineering, architecture, pharmaceuticals, consumer products, education, entertainment, medicine, space missions, the military,

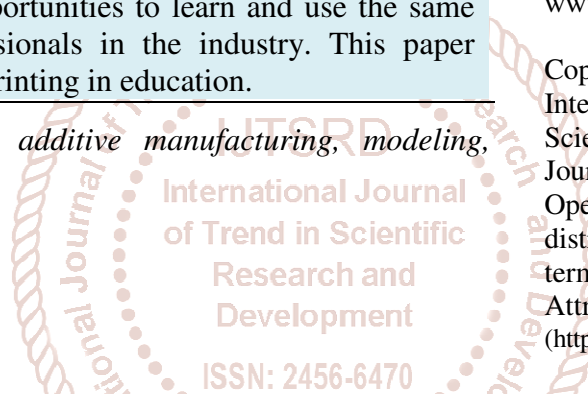
chemical industry, maritime industry, printing industry, and jewelry industry.

A 3D printer works by “printing” objects. Instead of using ink, it uses more substantive materials—plastics, metal, rubber, and the like. It scans an object—or takes an existing scan of an object—and slices it into layers, which can then convert into a physical object. Layer by layer, the 3D printer can replicate images created in CAD programs. In other words, 3D printing instructs a computer to apply layer upon layer of a specific material (such as plastic or metal) until the final product is built. This is distinct from conventional manufacturing methods, which often rely on removal (by cutting, drilling, chopping, grinding, forging, etc.) instead of addition. Models can be multi-colored to highlight important features, such as tumors, cavities, and vascular tracks. 3DP technology can build a 3D object in almost any shape imaginable as defined in a computer-aided design (CAD) file. It is additive technology as distinct from traditional manufacturing techniques, which are

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subtractive processes in which material is removed by cutting or drilling [2].

3D printing has started breaking through into the mainstream in recent years, with some models becoming affordable enough for home use. Many industries and professions around the world now use 3D printing. It plays a key role in making companies more competitive. The gap between industry and graduating students can be bridged by including the same cutting-edge tools, such as 3D printing, professionals use every day into the curriculum. There are 3D printed homes, prosthetics, surgical devices, drones, hearing aids, and electric engine components. A typical 3D printer is shown in Figure 1 [3].

Before 3D printing was introduced in the classroom, teachers relied on pre-designed teaching aids to teach new material to students. Students and teachers were limited in expressing their ideas through writing and two-dimensional or three-dimensional drawings. Now 3D printing enables schools to cost-effectively make modeling part of the educational process. Educators, ranging from elementary school to university, can apply 3D printing in classrooms to show physical prototypes. 3D printing meets current educational requirements for STEM. It will make the dreams and creativity of students and teachers at all levels become reality. 3D printing will become an important driving force to encourage innovation among students and teachers [4].

3D printing is the means of producing three dimensional solid objects from a digital model. It has been regarded as one of the pillars of the third industrial revolution. It could become an instrumental learning tool, helping to illustrate learning fundamentals, inspiring creativity in learning, and educating students to think outside the box. Today, if a student can dream it, he or she can create it with 3D printing. As professionals across almost every industry continue to increase investment in 3D printing, the technology becomes an ever greater part of our daily lives.

3D printing technology than can benefit educators in many ways. 3D printing is inspiring educators to develop creative ways for helping students. It provides teachers with 3 dimensional visual aids that they can use in their classroom particularly in illustrating a hard to grasp concept. Personalized educational aids can be 3D printed on demand. 3D printers can work as educational aids in classrooms. Educators are leveraging 3D printing to increase students' creativity and prepare the next generation of designers, artists, and scientists.

APPLICATIONS

3D printing has a variety of uses in numerous disciplines such as healthcare, aerospace, engineering, printing, manufacturing, entertainment, education, chemistry, mathematics, biology, history, and architecture. 3D printing in education is applied in the kindergarten, elementary, middle, and high schools, universities, libraries, technical colleges, and other educational settings. From K-12 schools to post-graduate college programs, 3D printing is a way for educators to encourage more active participation in the learning process. However, the needs of educators vary widely, from elementary teacher to university professor, there is not one job description. Thus, we cannot have one 3D printer that solves every problem. Every educator needs to incorporate 3D printing to provide the opportunity to learn more about the technology that is shaping the world. Figure 2 shown various uses of the 3D printer [5]. Some educational values of the 3D printing are demonstrated in the following applications.

- *Elementary School Education:* Introducing K-12 students to engineering design practices as early as possible can prepare them better for future education and careers

At the moment, 3D printers are in over 5,000 schools across the US. School children live in a concrete world while trying to learn the abstract. The 3D printing is an easy tactile medium for them to work with. There are some things in this world that our students could learn so much from if they had access to them. With a good 3D artist in a CAD program, those items could be recreated for any purpose. You can create appealing, accurate, and high-quality creations for the students with exciting student projects. The hands-on aspect of 3D printing in the classroom helps improve engagement and participation. Schools need robust, affordable, and user-friendly printers. XYZ Printing has been popular in education K-12 for years now due to the fact that it is easy to use and cost-effective. This is manufactured by a Taiwanese 3D printer manufacturer and it provides a complete K-12 STEAM curriculum to accompany its hardware. Another 3D printer most often found in classrooms is called an FDM (Fused Deposition Modeling) machine. Figure 3 shows an example of children using 3D printer [6]. Here are some examples of how schools and students can use a 3D printer in the classroom [7]:

- History students can print out historical artifacts to examine
- Graphic design students can print out 3D versions of their artwork
- Geography students can print out topography, demographic, or population maps

- Chemistry students can print out 3D models of molecules
 - Biology students can print out cells, viruses, organs, and other biological artifacts
 - Math students can print out 3D models of problems to solve
- *STEM Lesson:* The science, technology, engineering, and maths (STEM) program is an interdisciplinary approach to educating children from an early age with knowledge and skills in the four key disciplines of science, technology, engineering, and mathematics. STEAM (the A stands for Art) education builds on the foundations of STEM education and embeds the arts into its educational philosophy. STEM and STEAM naturally fit with project-based learning. Students integrate several disciplines including science, math, and design to understand concepts. Embedding 3D printing in STEM and STEAM learning encourages the critical thinking, problem-solving, and communication skills needed for future workforces. No technology enables STEM education better than 3D printing.
- *Higher Education:* 3D printing is widely applied in higher education. Universities play a major role in the diffusion of 3D printing. Some colleges have started to incorporate 3D printing in their curriculum whereby students are challenged to create a variety of chemical models. This motivates and engages students in learning chemistry, while at the same time acquiring the skills of innovation, collaboration, and technological literacy necessary for 21st century professionals [8]. For example, MIT offers courses at graduate and undergraduate levels that teach the basics of 3D printing. 3D printing is making the rapid distribution of up-to-the-minute anthropological discoveries to higher education reality. Researchers around the US use Fusion3 3D printers in a wide variety of fields. The Fusion3 EDGE enables the printing of high-quality objects at high speeds.
- Math students can print out “problems” to solve in their own learning spaces, from scale models to city infrastructural design challenges
 - Medical students can print human organs, develop prosthetics, and improve their own understanding of a human body
- *Medical Education:* 3D printing is a technology perfectly tailored for the healthcare industry. It offers a range of precision healthcare solutions, including tissue and organ fabrication; creation of customized prosthetics, implants, and anatomical models, drug delivery, and testing, as well as in clinical practice. There are several reasons 3D printing works well for medical applications and education. An on-demand 3D printing service can be used to quickly manufacture medical devices for patients in need. With 3D technology, one can rapidly create prototype devices and anatomy-based models for testing and training. For example, viewing a model from different angles helps students understand the steps involved in surgery more clearly. 3DP models allow student to view a patient’s anatomy. They enhance the students’ ability to provide out-of-the-box solutions for unusual challenges that require patient personalization. 3D printing is the ultimate tool for education and training in oral surgery [10]. For years, 3D printing has been used in the medical field for splints and implants. 3D models are also used for clinical training and patient education. In short, 3D printing increases the quality of the medical education. Figure 4 uses the use of 3D printing in medical training [11].
- *Engineering Education:* A 3D printer in the engineering classroom is akin to a toolkit for a carpenter. Students can experience design and creative engineering, and see their projects come to life in front of them. With 3D printing as the foundation for STEM learning, students have the resources to re-engineer the world. As the use of 3D printing continues to grow, there will be a demand for skilled designers and engineers to meet the demands of industry. A single 3D printer can be useful for multiple disciplines in science, engineering, and technology; paving the way for students to explore STEM. Technology students can work on developing new products using a 3D printing, for rapid prototyping and eventually production of real parts [12,13].
- *Mathematics Education:* Regardless of the academic discipline, a 3D printer will find its worth in any subject. 3D printing can be of great assistance when learning mathematics. 3D printing for mathematics offers a wide array of

Here are some of the ways 3D printing is used in higher education [9]:

- Engineering design students can print out prototypes
- Architecture students can print out 3D models of designs
- Cooking students can create molds for food products
- Automotive students can print out replacement parts or modified examples of existing parts for testing

options for student learning. It helps them to understand mathematics in a whole new way, visualizing everything from basic geometry to fractals. From kindergarten to graduate school, 3D printers are helping math students represent numbers and symbols with objects in the physical world. Any object represented by mathematical meaning can be printed and integrated into the curriculum. Designed properly, 3D printing can be used to teach fractions, decimals, algebra, and more. A typical 3D printer used in math education is shown in Figure 5 [14].

➤ *Architecture Education:* Interest in architecture is growing among students, partly due to 3D printers and digital modeling systems. From buildings to bridges, 3D printers provide a physical representation of the student's vision. 3D printing enhances a variety of educational experiences that architecture students are exposed to. Architecture and design students can print their models, making those tangible and having better ways of communicating their ideas. Learning basic CAD software and using 3D printers to create houses, landscapes, and objects provide a great way to generate interest in students. 3D printing helps students to fabricate their designs into 3D models for better display and visualization [15]. An example of 3D printing in architecture is shown in Figure 6 [16].

BENEFITS

3D printing is the cutting-edge technology that has been around for about 40 years. Businesses from various industries leverage 3D printing products and services to facilitate rapid prototyping, accelerate manufacturing, and simplify supply chain management. 3D printing has been incorporated in education for years. Academic institutions also leverage 3D technology to deliver a superior learning experience.

3D printing brings an object to life in real 3D. 3D printing has a major benefit of keeping interest for learners through a visual aid. The benefits of 3D printing for students are vast. The possibilities of educational purposes for 3D printers are endless. 3D printing and associated skills are transportable across disciplines. Since the 3D printers have come down in price and size, one of the most exciting applications of the technology has been in the classroom.

Other benefits of 3D in education include the following:

- 3D printing is a technology that scientists and engineers are using to change the world and solve real-world problems.

- 3D printing is a way to accelerate a typical manufacturing process.
- 3D printing is the ultimate tool for building engagement.
- 3D printing is widely used to develop practical skills that can be used beyond the classroom
- 3D printing gives students the ability to physically implement a prototype.
- 3D printing has opened up another way of thinking about curriculum.
- 3D printing is useful for validation research.
- With 3D printing, students can leverage their CAD skills to design a product idea.
- 3D printer transforms any class into an interactive learning experience.
- 3D printing can empower students to take their skills from the classroom into a new application.
- 3D printers can improve the learning experience in any situation.
- 3D printing makes it possible for every student to dream bigger and better.
- 3D printers are more affordable than ever and easier to use.
- 3D is used as the classroom technology to teach coding and problem-solving skills.
- It boosts communication and collaboration skills between students.
- 3D printers can bring almost any educational concept to life.
- Improves student creativity and design skills
- Promotes problem-solving skills and opens new possibilities for learning.
- It enhances hands-on learning and learning by doing.
- It provides more room for interactive class activities.

CHALLENGES

The step towards digitalization in schools costs money, but there is not much more money available to schools than their standard budget. Every nation should be aware of the future importance of 3D printing in many areas. There remain some challenges to widespread adoption of 3D printing in schools and colleges. 3D printing is still a very new technology that is not readily available to your average consumer. The finish of the models they produce is usually inferior to those produced with higher-end RP machines. Safety, security, accessibility, and ease-of-use are important concerns for using 3D printer in the classroom. Choosing a 3D printer with an automatic, lockable door ensures that the printer cannot be opened while it is working. Making your 3D printers easily accessible to students through a secure login takes care of security concerns.

Other challenges include the following:

- 3D printers are difficult to afford for most school budgets.
- It takes teachers some time to become familiar enough with the technology, find the right materials, overcome software issues, and fix technical faults.
- The choice of materials is often limited to just one or two colors.
- 3D printing is a process that takes some patience – not an asset that the average 12-year old has in abundance.
- Level of engagement drops and subjects become discouraging if the hardware involved is not fit-for-purpose.
- It is an intriguing new technology that is yet to find its place in the home.

These challenges can limit the value of having machines such as 3D printers in classroom.

CONCLUSION

3D printing is a technology that allows users to turn any digital file into a three dimensional physical object. 3D printing in education is the most exciting application. In education, 3D printing technologies facilitate improved learning, skills development, and increased student and teacher engagement with the subject matter. It has been a wonderful new way to teach and motivate students. With the decreasing cost of 3D printers, they have become an essential and valuable educational tool.

To use 3D to teach STEM subjects, it is important to have the right tools in place. The choice of the right 3D printing technology depends on the projected size and number of the models. Other major factors to consider in purchasing a 3D printer include ease of use, reliability, safety, cost-effectiveness, and print speed. It may be expedient to start with do-it-yourself 3D printer kits before purchasing. The use of 3D printers in education is growing at a rapid pace at all levels. The future for 3D printing at education industry is unlimited. For more information about 3D printing in education, one should consult the book in [17-21] and the following related journals:

- American Society for Engineering Education,
- International Journal of Progressive Education
- EURASIA Journal of Mathematics, Science and Technology Education

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Figure 1 A typical 3D printer [3].

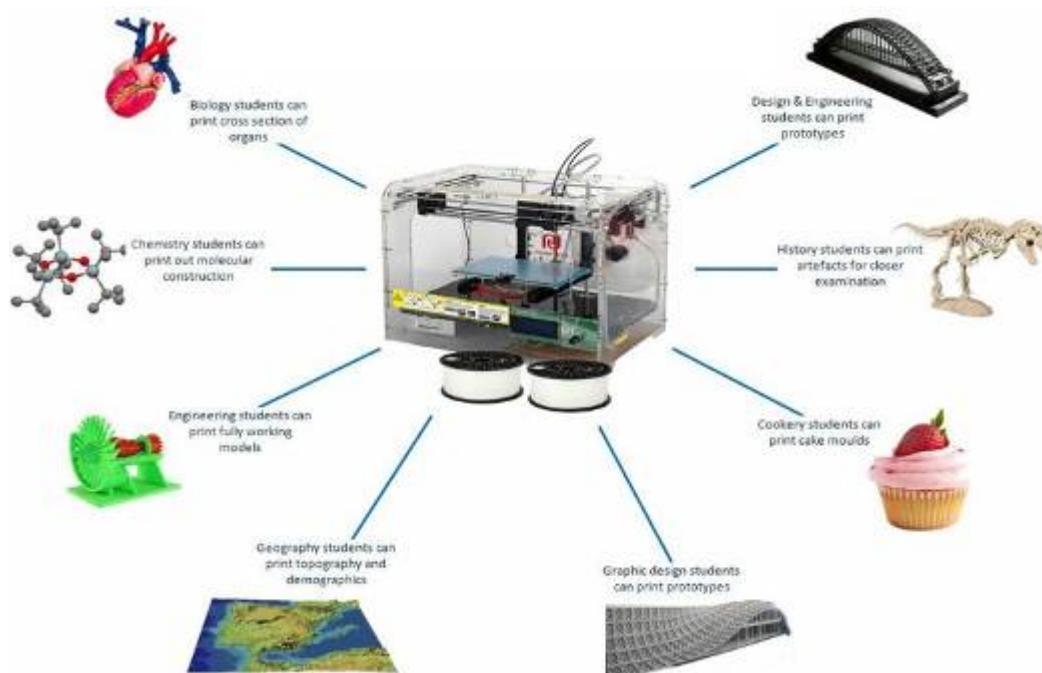


Figure 2 Various uses of the 3D printer [5].



Figure 3 An example of children using 3D printer [6].



Figure 4 The use of 3D printing in medical education [11].

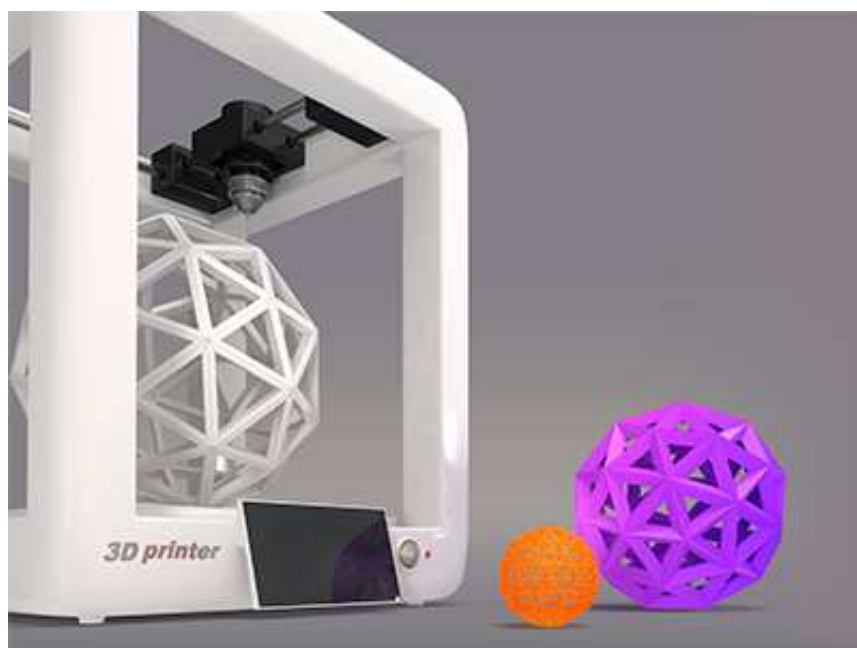


Figure 5 A 3D printer used in math education [14].

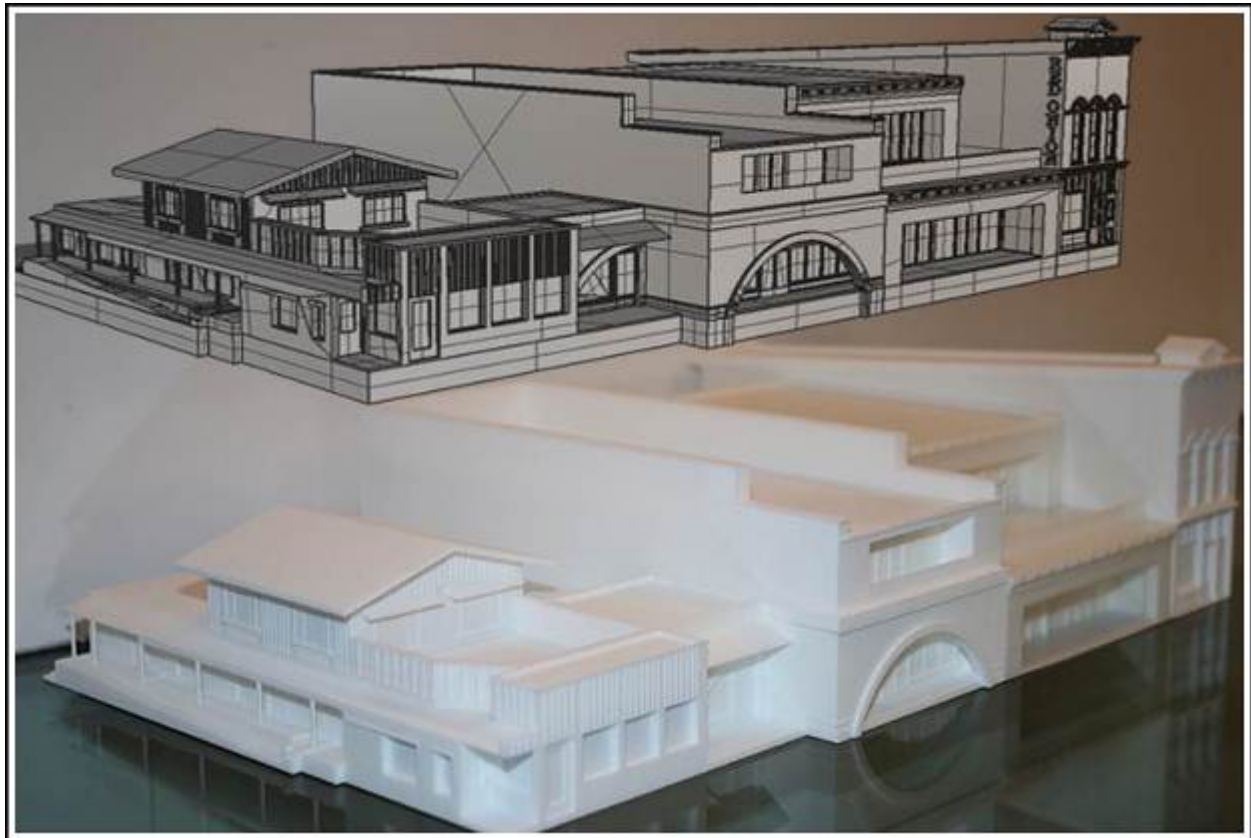


Figure 6 Examples of 3D printing in architecture [16]

