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Effectiveness of 3-D Printing Technology in Education and Teaching-Learning

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Abstract

Education is the key to releasing the true potential of human ingenuity. The emphasis of education should be on both academic and practical, hands-on techniques. It covers the gap between conceptual understanding and real-world execution. 3-D printing, a new educational technology, claims that it will equip pupils for a more technologically advanced future. By incorporating 3-D printing into education, cutting-edge technology is made accessible to ambitious students and future entrepreneurs. In order to help students' development of spatial cognition, three-view graphics are routinely incorporated into traditional methods of teaching. 3-D modelling helps students to enhance their design, critical, and problem-solving skills. The real potential of 3-D printing in education must be anticipated and understood by today's educators. Classrooms ought to be settings for experiential learning and real-world application. Teachers can personalise the three-dimensional printing technology and model to fit certain needs and even ensure their learning lessons are inclusive and accessible. Three-dimensional printing using novel and recyclable materials, which inspired the students to consider the consequences for the environment. But still, high costs, technical expertise, and availability of resources must be addressed. Due to their versatility, 3-D printers can support the dissemination of information and practical skills in a variety of subjects, including mechanical engineering, mathematics, science, biomedical, and architecture, to name a few.

Keywords: 3D printing, teaching, learning, education, challenges.

INTRODUCTION

3D printing, often known as additive manufacturing, is the technique of creating robust, three-dimensional items from digital data. Additive manufacturing is the process of adding layers of material, one at a time, to create a 3D-printed product [1]. Each layer can be seen as a thin slice of the product. subtractive manufacturing is the antithesis of 3D printing, where a milling machine is used to cut out a thin slice of metal or plastic.

3D printing is one of the most popular digital fabrication technologies out there right now. It's a way to make things that exist by putting materials together in a geometric shape. It's used in a lot of different industries, like farming, healthcare, cars, locomotives, and aviation, and it's used to create lots of different designs that can be open source [2]. It is a completely novel instructional tool that claims that it will equip students for a world where technology has progressed. Here are the most prevalent conceptualizations and learning outcomes in 3D printing research. [3]. 3D printing is a new educational technology that claims to prepare students for a technologically advanced future. Studies on 3D printing assess the most common theoretical positions and educational outcomes associated with 3D printing [4]. 3D printing is part of the maker movement because it encourages

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active learning, inventiveness, design, and problem-solving. It's also connected to STEM education because it ties together a lot of STEM fields, especially engineering and tech. But just because you set up a 3D printer doesn't mean you can use it to teach and learn. You need tech and curriculum support to get the most out of 3D printing [5].

Students were able to better understand how rendering algorithms could be applied as a teaching tool, educators were able to quickly prepare visual aids for the classroom, and researchers were able to develop their abilities in the integration of digital datasets with 3D-printed models to support societal and technical goals [6]. AI is making it possible to create really advanced tech. 3D printing is now able to take full advantage of AI, and it's expected to be used in lots of different areas during the fourth industrial revolution. It's seen as a game-changer for the future and can be used in a lot of different industries, like manufacturing, architecture, and healthcare. We still need to figure out the best ways to teach 3D printing, but it's more important than ever to teach students how to use and benefit from 3D technology. [7]. In order to advance societal and technical objectives, researchers have developed the ability to link digital data sets to 3D-printed models, educators have been trained in the efficient preparation of visual aids for educational purposes, and students have been taught how rendering algorithms can be utilized as a learning tool [8].

The additive manufacturing process involves the addition of material in order to form the desired shape, rather than the removal of material to form a part. In the Table 1 we can see the different additive manufacturing techniques on the basis of material state.

What Is 3D Printing and How Does It Work?

After CAD modelling of a product layer by layer, additive manufacturing is considered a process for combining materials to create components. The process starts with a virtual solid model. The model's data is then converted into a series of 2D cross-sections that are sent to an additive manufacturing system. Layer by layer, these cross-sections are combined to create the final part. The basic concept behind almost all additive manufacturing technology is this [17].

In accordance with ASTM, additive manufacturing is: "Instead of using subtractive manufacturing techniques, the process of combining materials to create objects from 3-D model data typically involves layering materials" [18]. Fused filament fabrication, or FFF, will be employed among all AM techniques because of its many advantages. Fused filament fabrication (FFF) is a 3D structure that is constructed layer by layer with thermoplastic filament driven by a heated nozzle, reducing the amount of waste generated. The aerospace, medicinal, functional prototype, food processing, automotive, and educational sectors all use additive manufacturing, a cutting-edge approach. Production units encounter considerable challenges as mechanical designs get more complicated, including greater costs and longer lead times. Manufacturing is an industry that is constantly developing new, effective methods [19]. Additive Manufacturing can be classified (Fig.4) on the basis of Whether staring material was liquid, solid or powder.

The primary application fields are as follows:

- Specialised parts, including those for the military, aerospace, and biomedical industry
- Prototyping
- Domestic usage
- Future uses will include construction, architecture, and transportation.
- Education area (Figure 5)

Materials Frequently Utilised in 3D Printing

There are a variety of materials available. These materials are all different in their properties, advantages, and disadvantages. Important elements like material kind, pricing, texture, and others must be considered in 3-D printing to prevent errors [20, 21].

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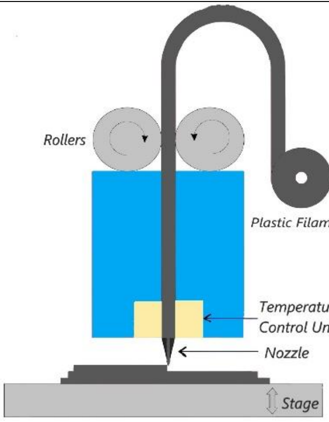
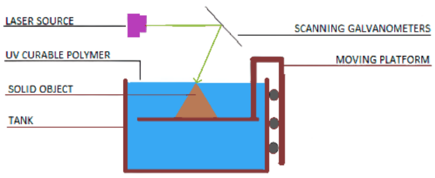
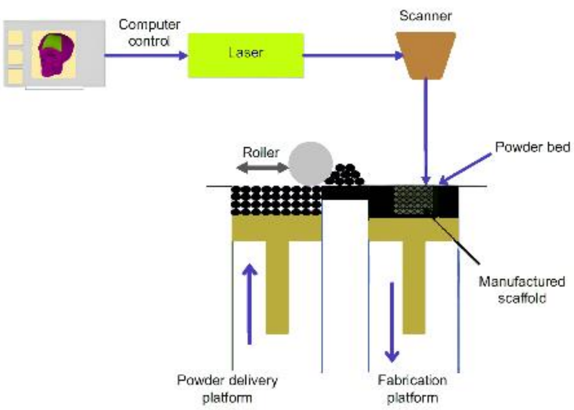
Table 1. Rapid prototyping techniques.

S.N.	Material State	AM Technique	Schematic Diagram and Description	Application	References
1.	Filament	FDM	 **Figure 1.** FDM Process. Direct 3-D printing is not the only additive manufacturing technique; fused deposition modelling (FDM) is another. Stratasys, Inc. has trademarked the FDM technique (Fig. 1), which involves employing incredibly small nozzles to inject molten plastic into tightly spaced lines. FDM can produce items with details as tiny as a millimetre or less.	Model for Conceptualization and Presentation, Biomedical Laboratory Equipment, Precision Casting, Architecture, Education, etc.	[9-12]
2.	Liquid	SLA	 **Figure 2.** SLA Process. A laser is used in stereolithography (Fig. 2), one of the Rapid Prototyping techniques, to gradually solidify the liquid resin required to build three-dimensional objects.	Biomedical, prototypes for conceptualization and evaluation, highly precise casting (such as injection moulding), parts for prototype tooling, etc.	[13,14]
3.	Powder	SLS	 **Figure 3.** SLS Process Powder Bed Fusion methods, such as Selective Laser Sintering (SLS) and Selective Laser Melting (SLM), involve the use of a high-energy laser or electron beam to selectively melt powdered material contained in a bed layer by layer (Fig.3). A recoater system deposits a thin, uniform layer of powder on the build platform.	Health and medical, investment casting, jigs and fittings, wind tunnel test model, functional model, and functioning prototype etc.	[15,16]

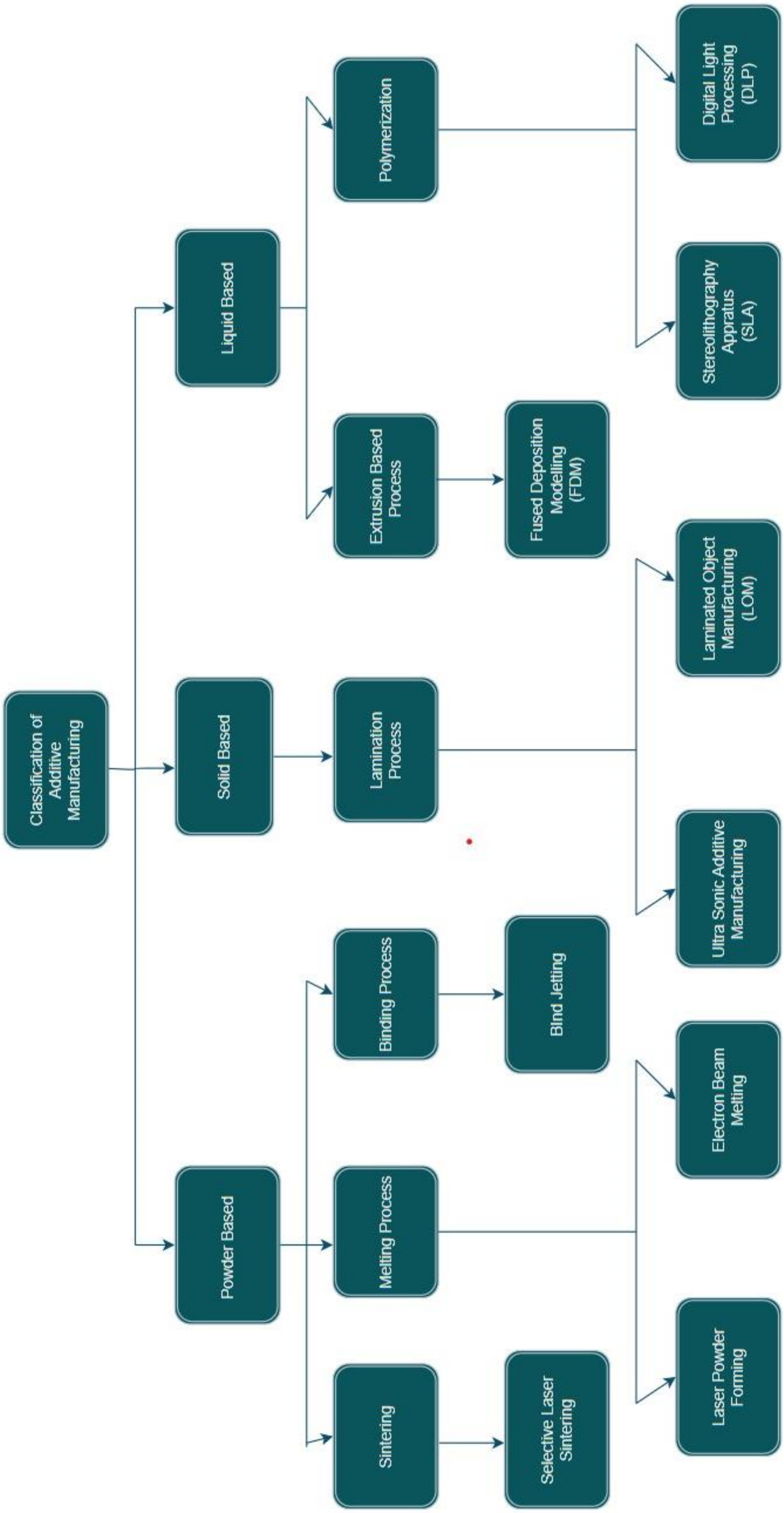


Figure 4. Classification of 3-D Printing Process.

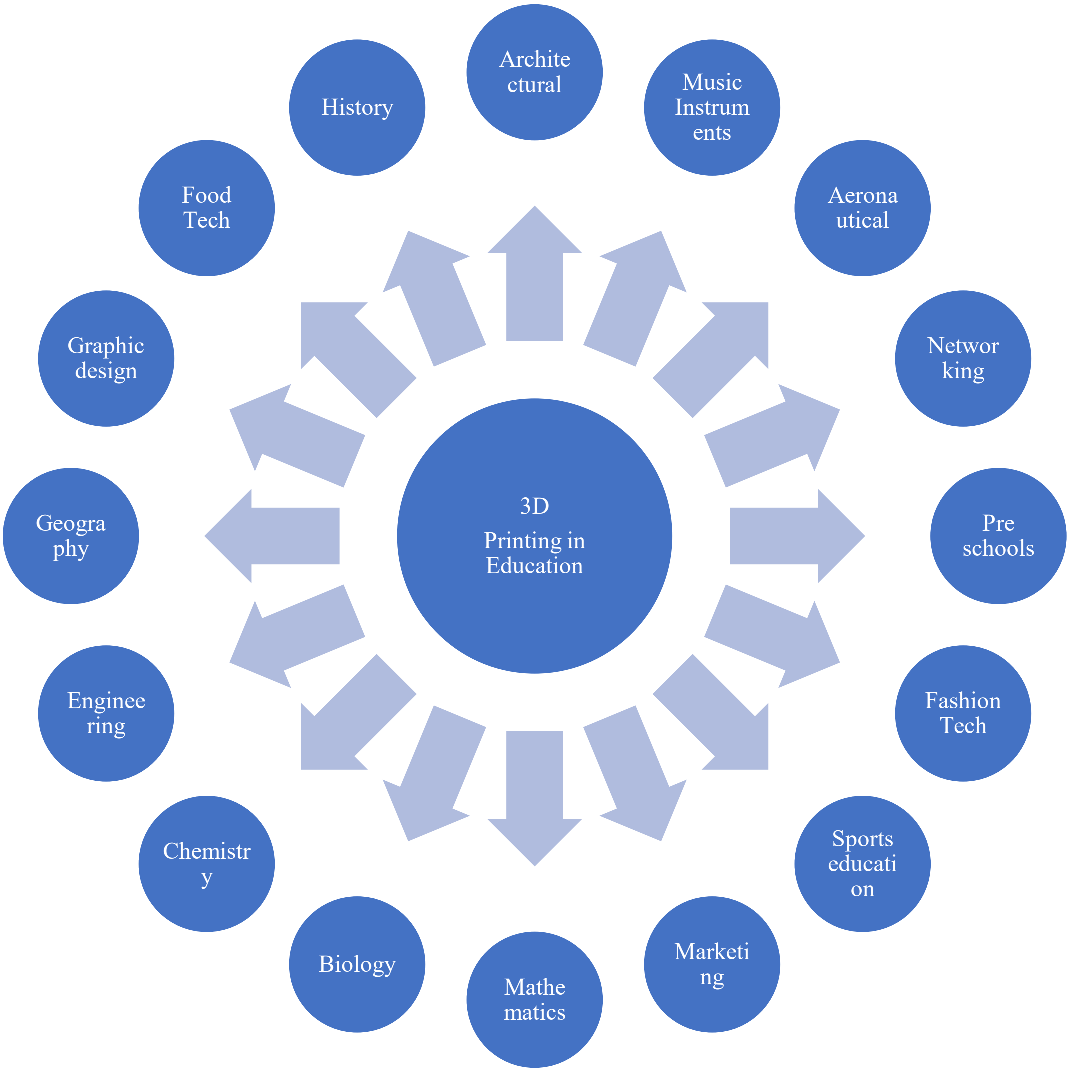


Figure 5. Application of 3-D Printing in Education.

Figure 6. 3-D Printing Material.

3-D printing uses a very small portion of the world's total supply of metals, alloys, composites, and polymers. On the other hand, 3-D printers use a wide range of common, valuable, and unique materials. Any business can expand by using components like polymers, composites, carbon fibre, and others. Choosing the material (Figure 6) for a task might be challenging [22-23].

- ABS filament is the most widely used plastic material for 3D printing.
- Nylon-Polyamides, which are composed of semi-crystalline structures, have an excellent balance of chemical and mechanical properties that provide good stability, rigidity, flexibility, and shock resistance.
- PLA-PLA is among the simplest materials to print, but it has a propensity to slightly contract after 3-D printing.

If you have the necessary tools and skills, you can effectively use 3-D printing in the industrial setting. More materials will be used to produce prototypes that are compatible with different 3-D printers as the 3-D printing industry grows. With any new procedure or piece of machinery, there is a steep learning curve that gets steeper as you move from plastic to metal 3-D printing. The process chain refers to the steps (Figure 7) required to create an appropriate product. The process chain begins with the ideation, CAD model and progresses through CAM, 3D printing, and post-processing.

3-D Modelling

Any surface or object can be represented in three dimensions by manipulating polygons, edges, and vertices in a fictitious three-dimensional space. 3-D modelling is frequently used in movies, cartoons, and video games to create inventive and unusual animals and structures.

Teams can build any shape while preserving manufacturing capacity by using 3-D models, which makes it reasonably straightforward to put thoughts together. Rough drawings or 2-D designs are unable to offer the design depth that modern 3-D modelling does, such as better detail control.

Benefits associated with 3D modelling for learners

The effectiveness of teaching and learning is now given top emphasis by all parties involved, including management, universities, industry, instructors, students, and parents. Over the past few decades, there has been considerable growth in our understanding of how people learn, but there hasn't been much of a connection between this knowledge and institutional teaching practices. Lectures are still the most common type of instruction [24].

- **Realistic**, By employing a 3D model, three-dimensional objects appear more realistic. The design can then be assessed before the prototype is made. Physical models are being utilised less frequently in the design business in order to save time and money, and more digital stages are being employed in their place.
- **TV shows and Gaming**: A lot of equipment is needed to shoot a TV show or a movie. Broadcasting professionals typically pick 3D printing over manufacturing since it is easier, more affordable, and faster because most of them are unique and only need to be made once.
- **Science Classes**: Due to the advancement of 3D printing technology, it is now possible to analyze the chemical composition from all angles. It may be handled and held in your hands, which increases understanding. Through a variety of educational projects, 3D printing promotes creativity and enhances students' knowledge of physics and maths. For instance, students can easily create intricate models and 3D print them to better understand physics principles.
- **Interactivity and participation:** The use of contemporary technology in the curriculum increases engagement and participation, even among students who are acquiring theoretical material.
- **Methodical, hands-on approach**: Using 3D printing in the classroom allows students to go from being passive consumers to active makers. The current approach lays a large emphasis on theoretical learning and less attention on applying information in the real world. Thanks to 3D printing technology's accessibility, more students may learn by doing.

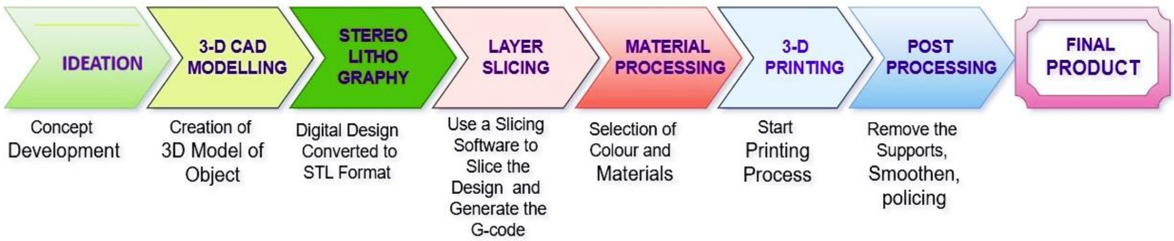


Figure 7. Steps in 3-D Printing.

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Improves Classroom and Online Learning

- Empowering educators to effectively incorporate 3D printing into their curriculum.
- most children learn more well when they are engaged, in pleasant classrooms. By utilizing 3D printing technology, educators may be able to develop engaging courses for difficult theoretical topics that transfer the process of learning from a computer to the hands of students [25].
- Increasing students' aptitude for design and creativity.
- Students gain knowledge of 3D printing, how it operates, and potential applications (such as speeding industrial operations) in the real world.
- 3D-printing things that help kids understand important concepts (like anatomical objects).
- Creating printed materials to aid students in understanding important concepts.

Some additional benefits [26]

- Measurables
- Eliminating language barriers
- Improving project approvals
- Making it simple to make changes
- Expanding the design
- Sustainable and constructive (Figure 8)
- Increasing quality and efficiency

Application of 3D in Teaching - Learning

As per Industry Insight [28], 3D printing is widely used in educational settings (Table 2) for a variety of purposes, including teaching and learning:

Generate Excitement

Students may be involved in the design process from the initial model phase to the final 3D printing of the model. As they gain hands-on experience with the design process, their enthusiasm and understanding of the process increases. As the student progresses through the project, the unique features of the project become more evident. The opportunity to explore concepts in a real-world setting rather than being limited to a screen or textbook adds to their enthusiasm. In addition to providing new learning and activity opportunities, 3D printing allows students to interact with the real world.

Figure 8. 3-D Printing Advantages.

Strengthening the Curriculum

Strengthening the Curriculum utilization of 3D printing technology can have a positive impact on the productivity of both students and instructors, regardless of the topic being discussed. By eliminating the need for students to simply passively consume information from a computer screen, students can become more involved in the process of creating, designing, and executing projects. This includes engaging with the printer and the instructor, which is in contrast to the typical classroom setting where students tend to become bored.

Teaching and Experimentation in Medicine and Dentistry

The medical industry (Figure 9) is one of the first to take advantage of 3D printing, and it's a sector that has a lot of potential to grow. Not only can 3D printing create customized and personalized products, but it can also help improve people's lives by creating processes and materials that are up to medical-grade standards [29].

Aerospace

The aviation sector was one of the first to adopt 3D printing technology as a means of product development and prototyping. Currently, numerous aviation interiors are in use, and further developments are underway [30]. Due to the importance of aeroplane development, R&D is challenging, standards are essential, and industrial-grade 3D printing technologies are being tested. The advancement of processes and materials has been extremely beneficial to the aeronautics sector. There are presently a number of non-critical parts utilised in aircraft [31].

Provides Access to Knowledge That Was Previously Isolated

Teaching students the basics of 3D printing is an innovative and enjoyable activity due to the fact that most printers are already manufactured and prepared for use. Students are encouraged to make mistakes on their first attempt and to strive to correct them. They are no longer intimidated by the idea of putting new and unconventional concepts into practice, as they understand that failure is an integral part of the learning process. Additionally, teachers benefit from having students who are motivated and confident.

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Table 2. A description of typical 3-D printing applications in various educational settings.

Which educational applications for 3D printing already exist?					
		Schools	Universities	Libraries	Special education classrooms
Role of 3-D printing can play in the educational system [27]	Teaching about 3-D printing to students	Students are first exposed to 3-D printing and 3D modelling in class while working on design and prototype projects.	Students studying engineering and design are introduced to the principles of 3-D printing and 3-D modelling, and they put their knowledge to use in class projects.	Enhancing access to 3-D printing resources and services enables students to pursue independent study outside of the classroom.	——
	Teaching 3-D printing to teachers	In-service teachers are being taught 3-D Printing and 3-D modelling.	Three-dimensional modelling and printing are being taught to pre-service and in-service teachers.	Librarians can operate, maintain, and debug 3-D printing equipment if the right training is given to them.	——
	using 3-D printing in the classroom	using 3D printing in class projects to increase student interest in and mastery of STEM subjects.	STEM classes are more easily comprehended by students and become more interesting for them thanks to the usage of 3-D printing in class assignments.	——	using 3-D printing to provide specialist instructional resources and flexible equipment.
	Creating educational items with 3-D printing	——	——	In lectures and lab sessions, 3-D printing models facilitate hands-on learning, especially in the teaching of chemistry and anatomy.	——
	Making assistive technologies with 3-D printing	——	——	——	Increases the variety of educational options for students, especially for those who have visual impairments.
	Utilising 3-D printing to assist outreach efforts	The use of 3-D printing in university outreach initiatives raises student interest in STEM fields.	——	——	——

Opens Up New Learning Chances

An inexpensive 3D printer offers students a wide range of educational opportunities. Students now have the opportunity to test their ideas thanks to 3D printing, which promotes and nourishes innovation. For younger kids, problem-solving might be challenging without the aid of graphics. An environment that provides children with the opportunity to interact with and observe their artwork can help to improve their understanding of the world around them. The use of 3D printers creates new possibilities for effectively and affordably educating young children.

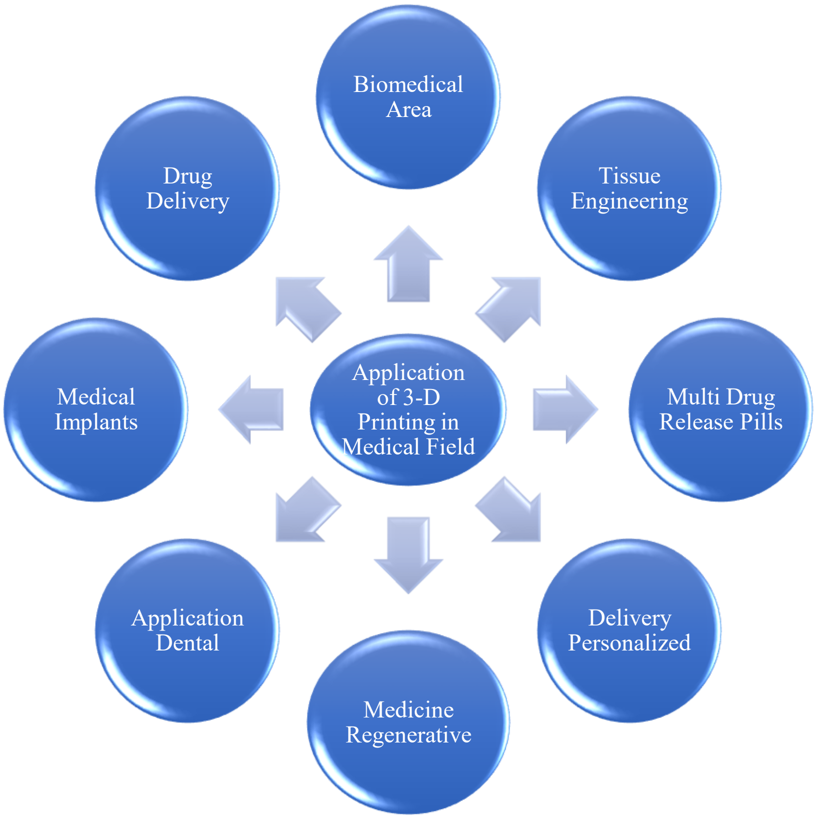

Figure 9. Application of 3-D Printing in Medical.

Promotes problem-solving abilities

Students have access to a range of educational opportunities thanks to the 3D printer. Students must gain an understanding of the various types of 3D printers, their operational capabilities, diagnostics, and other relevant skills. Many pupils might not have the opportunity to regularly practice this form of art as part of their academic curriculum. Students develop their aptitude for problem-solving by learning how to identify and fix 3D printer issues. Furthermore, it can assist pupils in resolving their own personal issues.

Creating a Hands-On Learning Environment

Students enjoy class more when they're actively engaged. There's no limit to how many slides can keep their attention and spark their interest during class. By making learning interactive through 3D printing, students can use their critical thinking skills to build their projects. They learn better and develop skills such as problem-solving in interactive classes. 3D printing benefits tactile learners just as much as visual learners, helping kids with a wide range of learning preferences.

Consumer Products

International catwalks have featured footwear, accessories, hats, and bags that were 3D printed. To showcase the possibilities of technology for haute couture, even more, avant-garde fashion designers have shown dresses, full-length gowns, capes, and even specific undergarments at international fashion shows [32].

3-D food printing

The practice of additive manufacturing is used to print food in three dimensions. The printing ink is typically held in food-grade syringes before being extruded via a nozzle constructed of the same material. The top 3D food printers allow you to make your food remotely on a computer, phone, or other IoT device and come pre-loaded with recipes. Because food may be changed in terms of shape, colour, texture, flavor, or nutrition, it plays a key role in a variety of industries, including healthcare and space travel [33].

Architecture, construction, and related industries

When 3D printing technology is used in these sectors, it can be viewed as a derivative that is ecologically benign and provides a number of chances for attaining geometric complexity. Using 3D printing technology, construction businesses can create complex structures or specialist construction elements.

Additive manufacturing has become a common technology of use in operational procedures. Rapid prototyping and 3D printing have revolutionized the manufacturing industry. Modern computer-aided design software is used as a complex method of part production [34].

Challenges of Implementing 3D Printing in Education

There are difficulties in incorporating 3D printing technology into the educational system, despite its many benefits [35]. Educators thought that integrating 3D printing would help students, but they faced several challenges, such as logistical and technical problems, as well as a lack of time and resources [36]. Some educational institutions, particularly those with tight budgets, may find the high cost of 3D printers, materials, and maintenance to be prohibitive. Teachers must also go through a learning curve to gain the necessary skills to use the technology and instruct students. Educational institutions can implement shared resources among institutions, obtain grants, or look for partnerships with leaders in the industry to overcome these obstacles. To guarantee the successful use of 3D printing in classrooms, curriculum integration techniques and teacher training programs are also crucial.

CONCLUSION

Three-dimensional printing technology has the ability to revolutionize education through increased imaginative thinking, broad acceptance, and interaction. Hands-on experience, creative thinking, and learning are encouraged by equipping students with the necessary technology and problem-solving skills for their future careers. The advantages of 3D printing in education exceed these drawbacks, despite ongoing issues with cost and training. The adaptability of 3D printing technology can support students' top-notch performance. Teachers from different academic levels and disciplines may provide students with a better, more interesting learning experience and help them meet learning objectives by using 3D printing. Student's imaginations can be piqued, and they can see how subjects link to the real world thanks to 3D printing. The combination of theoretical and practical abilities, as well as the capacity to visualise and comprehend academic subjects, are all benefits. The medical, scientific, and mechanical areas are only a few examples of the many different vocations. Manufacturers are starting to use 3D printing, which has many advantages for learners, educators, businesses, and even the government. Therefore, it's critical to keep looking at techniques to hasten the adoption of 3D printing.

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