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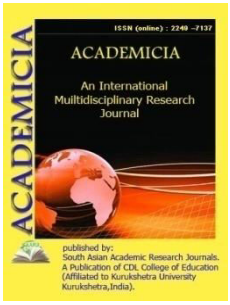

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AN OVERVIEW OF 3D PRINTING IN EDUCATION

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ABSTRACT

In a variety of topics and educational contexts, the development of additive manufacturing and 3D printing technology is creating industrial skills shortages and possibilities for innovative teaching methods. As a result, research on these behaviors is developing across a broad variety of education fields, although frequently without reference to other disciplines' research. To address this issue, this article brings together disparate sources of research to offer a current literature overview of where and how 3D printing is being utilized in education. Six use categories are identified and described as a result of research into the application of 3D printing in schools, universities, libraries, and special education settings: (1) to teach students about 3D printing; (2) to teach educators about 3D printing; (3) as a support technology during teaching; (4) to produce artefacts that aid learning; (5) to create assistive technologies; and (6) to support students. Although evidence of 3D printing-based teaching methods can be discovered in each of these six areas, adoption is still in its early stages, and suggestions for future study and education policy are offered.

KEYWORDS: *3D Printing, Education, School, Student, University.*

1. INTRODUCTION

As you may be aware, additive manufacturing is becoming more popular in a variety of sectors. To utilize 3D printing, you must first comprehend it. It is no longer necessary to demonstrate the significance of 3D printing in professional degrees. 3D printing has a wide range of applications, and it is currently utilized in a wide range of sectors for product development, manufacturing, tooling, and prototyping. Additive manufacturing will be present in increasingly more sectors in the near future, and education's job will be to educate students for future professions. Furthermore, 3D modeling and 3D printers can readily bring any educational topic to life, and 3D printing helps students develop strong practical skills such as coding and design thinking. There are a slew of benefits to using 3D printing in schools[1]. 3D printing and its close cousin, additive manufacturing, are digital fabrication technologies that are slowly but steadily challenging the industrial sector. While 3DP is still useful for fast prototyping and tooling, it is its use as a direct production technique that is causing widespread systemic upheaval This disruption is taking place as 3DP gains momentum in areas where its present degree of technical complexity aligns with market requirements. Improvements in productivity and quality are being made, but a number of studies and reports looking into 3DP and digital fabrication have warned that a lack of 3DP education and skills is a major barrier to wider adoption.

As a result, it is essential to look at the present state of research on the implementation of 3DP in the educational system. The education system is defined as elementary and secondary schools, as well as institutions of further and higher education, for the sake of this analysis[2]. It examines the use of 3DP for instructional reasons rather than research. Furthermore, this study does not examine the use of 3DP for instructional objectives in an industrial setting. Prior research on 3DP has focused on how students learn about the technology, how educators learn about the technology, how design skills and methods for creativity are taught, and how learning may be facilitated via the creation of artefacts, according to a review of previous studies[3]. Across the K-12 spectrum and in colleges, as well as in libraries, makespaces, and special education settings, such activities are taking place. Before delving into these issues in depth, we'll give you a quick primer on 3DP and the use of digital fabrication technology in education[4]. In contrast to other general-purpose technologies, 3DP refers to a group of technologies that use additive layer-by-layer digital fabrication to create three-dimensional things. “Additive manufacturing” (AM) is described as “a technique of connecting materials to create things from 3D model data, typically layer by layer, as opposed to subtractive manufacturing methodologies” in its official nomenclature.

ASTM recognizes seven kinds of additive manufacturing, and a broad variety of goods based on these types are available on the market. Fused deposition modeling (FDM), stereolithography (SLA), selective laser sintering (SLS), selective laser melting (SLM), and digital light processing (DLP) are some of the most commonly used 3DP technologies, although new additive processes are still being researched and commercialized[5]. While polymers were first utilized in 3DP for prototyping, a considerably broader range of polymers, metal alloys, composites, and ceramics have since been created for use in digital manufacturing, with the kind of 3DP method used and the intended application dictating their usage. In comparison to other subtractive and transformational manufacturing methods, 3DP is an additive manufacturing process. In comparison to these methods, 3DP has a lot of benefits. However, being an emergent technology,

it is still in its early stages of development; it has yet to reach its full potential, and there are extra socioeconomic obstacles to overcome due to the technology's novelty. Table 1 provides an overview of these benefits and difficulties. The main firms in the 3DP sector are presently Stratasys and 3D Systems. They may be traced back to the initial 3DP patents filed in the mid-1980s, and they've evolved from being only focused on the use of 3DP in fast prototyping to a broader use in digital manufacturing. New entrants in both the professional and consumer sectors have been lured by the sector's development. The latter has attracted the bulk of newcomers. The RepRap project, an open source effort to build a self-replicating robot, was the catalyst for the consumer 3DP boom. Members of the Maker movement all around the world were very interested in this project. This initiative, along with the development of crowd funding sites like Kickstarter and Indiegogo, has allowed a slew of new businesses to enter the market. The 3D printer is just a small part of the broader 3DP business ecosystem. The 3DP ecosystem comprises businesses that create 3D scanning technology, CAD software, and materials, as well as service bureaus and online distribution platforms, in addition to equipment makers.

1.1 Waysof 3D printing being utilized in education

The purpose of this review is to describe how 3DP is utilized in the educational system. The parts that follow provide a summary of the information. There are four major educational settings where 3DP is used: Schools, colleges, libraries, and special education settings are the four types of educational environments.Each of these sections provides a brief explanation of how 3DP is implemented. utilized in these situations

- The use of 3D printing in schools: 3DP in schools and children's environments. From basic through secondary school, education encompasses the whole range, from elementary to middle school, for secondary/high school students , as well as combinations of the three. However, since there are few publications that explicitly address elementary and middle school, they are grouped together. For the sake of this debate, secondary and high school are used. Physical prototyping, such as 3DP, may help students get a better grasp of science and arithmetic. The bulk of the articles in this body of work support this viewpoint, providing instances of how 3DP is being utilized in schools to enhance STEM teaching. In the sciences, for example, 3DP was utilized to teach atomic structure to Grade 10 chemistry students, with a favorable connection discovered. between the incorporation of technology into the classroom and student learning .Japanese high school pupils, on the other hand, studied about By producing 3D printed police whistles, audio frequency may be increased. In Students were exposed to 3D printer building, computational thinking via a mix of Minecraft and 3DP, and design thinking through a 3D printer. Kaysville, a printed city planning game. Other research focuses on design explained how pupils learned to be creative. Product design and development, as well as technical drawing. In elementary schools and high schools, students are developing prosthetic hands. A project-based learning study of a trans media book project It was discovered that utilizing 3DP enhanced students' mathematical performance, as well as their knowledge of geometry. Via the creation of three-dimensional forms STEM The use of 3DP in K-12 education has been used to achieve integration. Students learnt about the enormous extinct shark in paleontology.3D printed replicas of the teeth of Carcharoclesmegalodon. Furthermore, 3DP is being utilized in a number of STEM-related projects. School-based outreach initiatives. With the capacity to rotate 10 times,

visualizations may help with spatial instruction. Year-old boys are especially well-served. Many of the benefits of 3D printing are shown in the examples above. They enable self-directed creation and capability for autonomous and introverted labor, as opposed to virtual, screen-based artefacts. in addition to increasing physical tactility and observability. Created physical artefacts Incorporating 3DP into school curriculum is also beneficial from a pedagogical standpoint, since it may offer chances for collaboration. Various learning methods, including experiential learning, will be practiced. As well as failure. It was discovered in a study of two Greek high schools that. The usage of 3DP allowed for the exercise of various learning methods, including "We have found that this is especially helpful in engaging specific students: When given the appropriate motivation and resources, students who were otherwise uninterested in their project class (according to them and their instructors) may select what they want to study via inquiry Then students may proudly share their findings with others while gaining knowledge. rather than dry knowledge from textbooks.

- Universities that use 3D printing: Universities are the most likely to use 3DP in tertiary education. Moreover, there are just a few accounts of the technology's acceptance in the United States. additional institutes of higher education and continuing education Within Articles on the usage of 3DP at universities may be found in the literature. The usage of 3DP systems, scientific models, and test models; the development of 3DP systems, scientific models, and test models3DP during project-based learning; incorporating 3DP skill development into the curriculum by incorporating it into current curricula courses, as well as new course introductions; and external involvement outside of the university This section contains short descriptions of each in the series. Turn. There are many stories of how open source was created. Engineering courses are including RepRap 3D printers. A mechatronics design's main point is their construction. Jordan is working on a senior capstone project at Philadelphia University, which is funded by the Princeton / Central Jersey Section .The Institute of Electrical and Electronics Engineers' (IEEE) Professional Committee on Joint Standards (PCJS) (IEEE)and is utilized at the University of Applied Sciences Offenburg to teach 3DP to industrial engineering and business masters students. In this instance, students constructed the 3D printer first, then downloaded and printed 3D models. The sciences, where 3D printing is used extensively at institutions, are one of the most important applications of 3DP.In the lab or in the classroom, models are developed to aid student learning. This use of 3DP to create visual models In a similar spirit, This also contains test specimens for determining the mechanical characteristics of various materials.
- Materials test models made of 3D printed polymer have been shown tobe acceptable in engineering courses for this purpose, and Mechanical testing have been integrated into an undergraduate capstone research course at the University of Johannesburg's Mechanical Engineering Science Department. MSc graduate students at the University of Toronto's Faculty of Mechanical Engineering. During the fan and turbo compressor development, Belgrade utilized 3D printed components. Fourth-year aeronautical engineering students at Technion – Israel Institute of Technology created several experiments.3D modeling was used to test various wing spoiler configurations and their effects. Wind tunnels using printed models.3DP has also become a popular teaching tool in robotics. Being a low-cost method of promoting educational development haptic devices and robotics. For the chassis, a 3D printed

chassis was used. Students may alter low-cost open source robotic systems. Robot, as well as to disseminate these changes to other students .3DP may be used to support project-based learning and other types of learning. Numerous articles have been written on the usage of 3DP in projects [6]. The University of Michigan is one example. Second-year mechanical engineering students in Modena and Reggio Emilia. Undergraduates utilized 3DP to design and build an app as part of a project. The State University of New York's eye-tracking system, and The incorporation of 3DP into the classroom increased student involvement. a semester-long design program called "Introduction to MEMS". During It was a master's degree in mechanical engineering at Politecnico di Torino. The use of 3DP in a project-based learning setting was shown to enhance student attitudes toward mechanical engineering. Specifically, it was discovered that using 3DP resulted in favorable student response. Motivation, comprehension, interest, and education of students[7].

- 3D printing in libraries: Libraries at schools , universities , and community colleges , as well as public libraries, medical libraries , and libraries in general , are all mentioned in studies that view the library as a site where 3DP happens. The use of 3DP in libraries is part of a broader discussion regarding the role of libraries in the digital age. Those opposed to 3DP in libraries claim that it is a "exotic cutting-edge technology-based service" that is "a simple luxury or a needless expenditure for what may only be a limited number of customers". According to the sample of publications examined here, this is a minority viewpoint, with the majority of articles expressing support for 3DP integration within library services. “In most companies, the library is a natural option to store technology that has many potential users,” says a more representative statement. Libraries can provide a significant service to their organizations by offering space and expertise for 3D printing while also increasing awareness of the other services they provide”. Libraries, as a physical place, facilitate cooperation and knowledge sharing among library users, librarians, and educators, as well as lowering obstacles to participation. As a result of this accessibility, maker spaces inside libraries have emerged as creative spaces where library users may use 3D printers and other digital fabrication technologies, with such places promoting innovation and experimentation.
- While the majority of maker spaces are formed inside libraries, there are many examples of maker spaces that are developed outside of libraries[8].The neutral, non-departmental area at universities enables for contacts between students from other faculties as well as extracurricular usage. “The library is frequently viewed as a non-disciplinary or cross-disciplinary place on campus, where all users have access to the resources and services,” Van Epps et al. write. By integrating 3D printing into our libraries, we are able to expand access to 3D printers from a select few to everyone”. While access to non-traditional library services such as 3DP may be enhanced, their adoption in university libraries may be limited. Running basic 3DP workshops and pop-up maker technology workshops may help increase awareness, as can finding local champions like design professors, 3D visual researchers, and design-oriented student organization. Groenendyk and Gallant describe how the library wanted to “take the knowledge-sharing, innovation-driven principles of hacker spaces and integrate them into an academic library setting” in their 3D printing and scanning pilot projects at Dalhousie University Library[3]. The library wanted to make 3DP available to students who weren't previously familiar with it, such as those studying engineering and architecture. The 3D printing and scanning technologies were chosen for their low cost and

ease of use. The librarians also anticipated that the 3D scanner would allow them to digitize and preserve different scientific and cultural items online. “By establishing this collection, the Libraries will contribute to providing online visibility for both student and faculty work, as well as ensuring that the 3D material gathered is maintained and publicly available”. Librarians play an important role in the integration of 3DP into a school or institution. “School libraries may act as test beds,” said Mark Ray, Chief Digital Officer of Vancouver Public Schools[9]. As others follow our example, teacher librarians may play an important role in assisting educators who are dealing with change and uncertainty in this brave new world”. Library personnel, as a central resource, not only assist people who come into the library, but also educators who want to integrate 3DP into their teaching practice. A partnership between a librarian and an instructor at LaGuardia Community College resulted in the creation of a biological model for in-class instruction. While librarians' time and skill in delivering such services is a limiting issue, providing them with training in the use of 3DP technologies may help them overcome their lack of knowledge and discomfort when dealing with library customers. Such fundamental training is required to offer student instruction, as well as to guarantee that library personnel can maintain 3DP equipment and resolve problems. Librarianship abilities will need to develop in tandem with technological advancements.

- The use of 3D printing in special education: For individuals with visual, motor, and cognitive disabilities, 3DP is being utilized in special education settings. Within these contexts, students with visual motor and cognitive impairments, as well as combinations of the three , have utilized 3DP[9]. The use of 3DP in these contexts allows for the development of customized adaptive devices and instructional aids, as well as increased student engagement in STEM topics, the use of 3DP to build assistive devices is explored in more depth. As detailed in Buehler et al two-year 's study into its uses using 3DP in special education settings has significant difficulties. Students with cognitive impairments were given lessons on how to use Tinkercad software before being invited to build their own 3D creations in one of their studies. However, due to the complexity of the job and the short time available, most students chose to print or alter designs from open-source websites rather than develop their own[7]. Due to the difficulty of utilizing the program, students' enthusiasm in creating unique designs seemed to wane, with problems noted in changing perspectives and manipulating items. Furthermore, students with high assistance requirements found it especially difficult to create in three dimensions. Other adoption issues developed as a result of the students' occupational therapists[8]. While excited about 3DP's potential, they were worried about the time and effort needed to learn how to use the program “they presently view 3D design and printing as someone else's job, and see themselves as consumers of that work[10].”

2. DISCUSSION

3D printing, also known as additive manufacturing, has been called the next big thing, with the potential to be as widely used as the cellular phone industry. 3D printers convert a digital blueprint into a real three-dimensional item. Plastic, metal, nylon, and over a hundred more materials are used in the printing process, which is done layer by layer (additive manufacturing). Manufacturing, industrial design, jewelry, footwear, architecture, engineering and construction,

automotive, aerospace, dentistry and medical industries, education, geographic information systems, civil engineering, and many more fields have found 3D printing to be beneficial. In every area of application, it has shown to be a quick and cost-effective solution. 3D printing's uses are growing all the time, and it's proving to be a really interesting technology to keep an eye on. We will look at how it works as well as present and prospective uses of 3D printing in this article.

3. CONCLUSION

The current research on the use of 3DP in the school system has been summarized in this article. This state-of-the-art study offers a better picture of where and how 3DP is being utilized in the educational system by synthesising a varied and fragmented literature of 280 articles. Table 6 contains a high-level overview. Given its history as a fast prototyping technique, it's no surprise that 3DP is most often used in university engineering and design programs, with specific 3DP courses developing from these fields. However, it is clear from this study that 3DP has grown beyond its origins; it is now being actively integrated into a number of different topics and is being utilized to create learning artifacts. Other STEM fields are the most visible users of 3DP outside of engineering and design, and they are starting to show how 3DP may establish cross-linkages across different topics. There are presently just a few recorded instances of 3d printers being used during in-class instruction in non-STEM disciplines.

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