Influence of Additive Manufacturing Technology to Manifest the Joy of Learning in Indian Education System

Dr. N Madan Mohan Reddy[1], Mr. G. Arun Reddy[2], Dr. K S Chalapathi[3], Dr. Md. Sikindar Baba[4]

[1,2,3,4]Department of Mechanical Engineering, Anurag University, Hyderabad.
[1]madanmohanreddymech@anurag.edu.in [2]arunreddymech@anurag.edu.in [3]kschalapathi@anurag.edu.in
[4]sikindar@anurag.edu.in

Abstract— In this study, the traditional educational system of India has been contrasted with the contemporary educational systems throughout the world using digital manufacturing technologies like 3D printing and computer numerical control (CNC). Aspects of the future of education will be revolutionized by this technology, as well. In order to explore the students' perspectives on the integration of this prototype technology into India's educational system, the study used semi-structured interviews. The data were analyzed using a content analysis approach, and the emerging themes were explored using verbatim texts. The results show that educators and students are really engaged and persuaded that, like computers design software, prototype technology would soon bring about another revolution in India's educational system. They depend heavily on contemporary teaching methods to convey novel concepts in concrete ways. They emphasized how this technology had affected their present methods and how elementary and basic education could use it to foster greater comprehension in creative minds.

Keywords—3D printing technology, Digital prototyping, traditional education system, India.

I. INTRODUCTION

Digital 3D models are transformed into physical products using additive manufacturing, or three-dimensional printing. However, over the past ten years, 3D printing has also begun to permeate the world's educational systems. However, most STEM (Science, Technology, Engineering, and Math) institutes, particularly those in developing nations like India (Mahmood, A 2022), continue to accrue investments in 3D

printing technology. The primary objective of this study is to investigate the wide variety of present and potential 3D printing uses in the cutting-edge educational period. (Aysegul Aslan 2022) states that the advent of 3D printing has just become a reality and is expanding quickly with the pace of new technological developments for practically all areas. Numerous users in India frequently restrict the development of 3D printing technology and its usage in numerous fields considering only at the limitations of the technology. Globally, 3D printing is being utilized on a bigger scale to enable educators and students to design more efficient learning methods and perform better using 3D printed models in classrooms (Aamer Nazir 2023). In addition to discussing several instances of the same subject (particularly in the fields of engineering and medical sciences), this study explains the significance and uses of the 3D printing processes and technologies that are now used both internationally and in India on the education system. This study also investigates the impact of 3D printed models and prosthetics on the present educational system. The higher education sector in the UK is now being investigated by a variety of research organizations and groups that are actively utilizing 3D printing technology in Art and Design settings (Chetan M. Thakar 2022).

Problem Statement: The foundation of a nation's growth is seen to be its educational institutions, which are also a key driver of global innovation. In the current educational principles of India, there is a problem with graduates generated using traditional teaching techniques (without interactive class learning), which are seen as inefficient results in the context of state growth (Banjanin, Bojan, 2020) in terms of graduates. Student centric teaching – learning practices are the talk of the educational bodies in these days. Effectiveness of learning but not delivering a lecture has more priority. Especially concepts of construction, structure and working models cannot be left to imagination of students after discussed theoretically to achieve effective learning. 3D printing technology comes to rescue in such scenario. This also aids in product development projects by students by shaping a physical form of an innovative idea.

II. LITERATURE

Significance of Proposed Technology: The ramifications of additive manufacturing for engineering and manufacturing must be substantial in terms of the economy, geography, geopolitics, environment, demographics, and security (Luo, Y., Zahra, 2023) considerations. We can anticipate the future of additive manufacturing and how it will have an influence on the global economy by keeping a watch on computer, internet, and global web technologies (Iqra Sadaf Khan, 2023).

In domains where most often technologies are used, such as engineering, science, technology, and math design, 3D printing applications go beyond prototype (Athanasios Goulas 2019). It has a wide range of applications in the education sector, including supporting teachers with 3D models they can use in the classroom, particularly to illustrate a difficult-to-understand concept, piqueing students' interests by showing models of objects, enabling hands-on learning via mini-models (engineering, architectural, and medical students), and by providing more space for interactive approaches in class activities (Faladrum Sharma, 2022).

Innovative Ideas to be Transmitted via Digital Manufacturing: Despite being disruptive, technology has improved lifestyle in a number of ways by opening up new possibilities. Additive manufacturing, often known as 3D printing, is one of these technologies (Mohd Javaid 2022). In actuality, 3D printing technology revolutionizes designs to fit social, geopolitical, demographic, and economic environments, despite what certain cultures assert (Sachin Kumar 2022). Mainstream industrialists can now produce

Fig. 1. Global Market Opportunities Forecast based on 3D Printing Market report and Wohler's 2023 report. (Source: https://www.marketsandmarkets.com/Market-Reports/3d-printing-market-1276.html & https://www.plasticstoday.com/medical/stratasys-desktop-metal-merger-creates-industrial-3d-printing-powerhouse).

personalized goods at reasonable rates by implementing 3D printing. People in today's modernized society do not desire identical items, thus manufacturers concentrated on providing customized products without charging extra. Due to the fact that 3D printed goods are often more expensive, they are produced to distinct cost requirements because it offers a completely new and strong product category. Mass production

is dominating in many sectors as it is known for low manufacturing costs. However, it is not cost-effective in any economy because it lacks customization, complexity, personalization, demand, and designing. 3D printing will contribute to a surge in the economy that is self-sufficient, remote-based, and decentralized and that marks the beginning of the industrial revolution (Abirami Raja Santhi 2023). Inflated expectations are at an all-time high for additive manufacturing and 3D printing. A new environment for booming innovation and application of this emerging technology with various sectors using 3D printing has emerged as a result of the falling costs of 3D printers and devices, the expansion of the variety of supporting materials and their accuracy, and the expiration of device critical patents (Tomy Muringayil Joseph 2022).

A major shift in the mechanical engineering education by introducing 3D printing: Thanks to 3D printing technology, Innovative thinkers, creators, and dreamers have a wonderful possibility to materialize their conceptual thoughts. In maker spaces, universities, and primary schools, this technology has a significant influence on many other areas (Daria Casciani, 2023). However, because practitioners lack sufficient expertise and awareness, the technology's advancement is gradual. Using 3D printing in education involves getting items out of computer screens and into students' hands for examination and hands-on experience. Globally, it is widely believed that postsecondary education leads to better-paying employment prospects (Hazem Ibrahim 2023). Use of 3D printing technology in higher education has grown in popularity as a tactile teaching tool (Branko Andic 2022). This cutting-edge technology enables students to experience concrete learning patterns that support their unfettered expression of interest, adaptable way of interaction, and presentation (Xinli Zhang 2022).
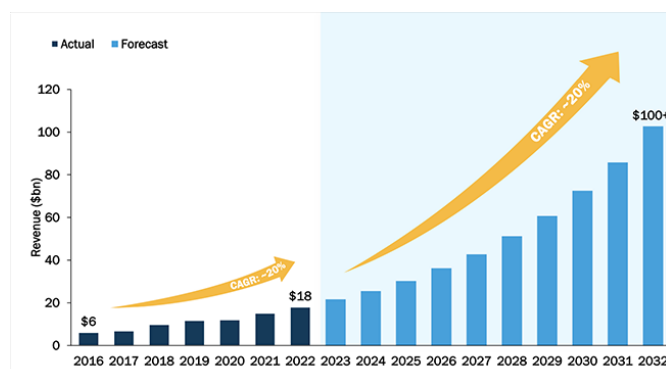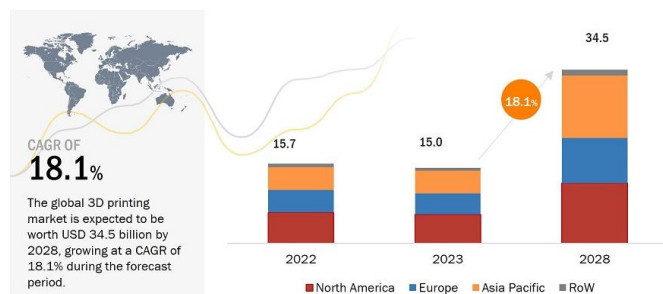
Nowadays, educational systems all around the world use the DIY philosophy, allowing students to follow the DIY phenomena in order to develop their own original ideas. To increase children's interest, interaction, and involvement in fabrication technologies (Muyiwa Oyinlola 2023), DIY learning methods include 3D printing technology into the educational system. By offering customization in designs at a lower cost, promote the use of contemporary technologies in STEM fields (Branko Andic 2022).

In industrialized countries, technology is used as a fundamental building component in education for practically all age groups. The failure of educational institutions and community cultures to accept the transition led to the mastering community's exodus (Gonzalo Nicolay Samaniego Erazo 2022). The change was therefore not straightforward. (Cheryl Lemke 2022), transforming the world into lonely, customized, introverted, and silent labor (Eisenberg, 2013), and generating positive changes in people's life generally.

III. METHODOLOGY

In order to examine the innovativeness of the educational system using 3-D printing technology, this study used a qualitative research methodology. According to Mahmood Al-Bashayreh (2022) this method has been utilized and approved in many different nations to investigate the results of study hypotheses. Students from many academic levels participated in the experiment, including PhD candidates, recent graduates, and undergrads. Hyderabad's Anurag University's Center for Research in Digital Manufacturing (CRDM) was chosen as the experimental facility. The facility has 3 FDM printers of different specifications and one SLA printer. FDM stands for fused deposition modeling, where molten polymer is laid in a controlled path and quantity along the geometry of the component to be printed. However soon exposed to atmosphere, the molten polymer cools and solidifies. SLA stands for Stereolithography, where a laser assumes the path of the geometry layer-wise in a pool of resin which is a photo polymer that solidifies upon exposure to laser light. The outcome approach employed in this study was semi-structured student observations. Purposive method, in accordance with Nanna Kaas Tepavicharov 2022, necessitates a range of undergraduate, PhD, and masters programs, 3D printers, and printing services. Table 1 displays all background information about the student.

TABLE I
RUBRIC FOR ASSESSING STUDENTS' LEARNING

Every response possesses knowledge of the technical aspects of 3D printing as well as practical experience. Each person has sufficient understanding about this issue to express their

Rubrics	Level-1 (Beginner)	Level-2 (Developing)	Level -3 (Proficient)
Creativity	Follows set of instructions to complete a design of any relevant product	Creates an original design of the product but mostly based on existing ideas.	Design is based on mostly original ideas highlighting disadvantages overcame.
Design	Makes a model of the product using basic tools.	Makes a model of the product using at least one design tool not used before.	A range of design tools used to create a well- structured, model of the product with all parts connected.
Print	3D model printed for look and feel of the product	Checks that model is ready for actual manufacturing and handling.	Makes changes or suggestions to ensure model can be successfully 3D printed.
Evaluate	Describe their completed design.	Describes how successful their design is with reasons and examples.	Evaluates model by how well it meets required criteria.

perspective. A rubric has been considered to assess students' learning as follows and record their feedback. experiences but can also offer adequate data. The opinions of four respondents were collected about the use of 3D technology in India's educational system.

IV. RESULTS & DISCUSSIONS

Based on the above methodology, the following outcome-based observations and feedback through peer evaluation were recorded officially and presented in this section. In proportion to various academic programs offered by the department, learnings of two UG students, one PG student and one research scholar were evaluated.

Observation 1:

Who I am:

I am Masetty Akshay completed my undergraduate education in Mechanical Engineering at Anurag University. I am a member of the AnuragSat Mechanical Department. I have published 4 research papers in esteemed UGC journals. My research paper on the topic "Comparative Study on Nose Cones with respect to Angle of Attack using CFD" won the best paper award at the RSRI Conference on Recent trends in Materials and its Characterization 2022 organized by REST Labs and was published in the REST Journal on Advances in Mechanical Engineering.

Now I have been selected for the MSc in Applied Mathematics at the University of Birmingham. I have also received the Birmingham International Scholarship Award in the amount of 2000 GBP.

How CRDM [Center for Research in Design and Manufacturing Engineering] was Useful:

The CRDM lab at our university was very helpful. At the lab, I was able understand to important topics such as CNC Coding in various machines such as milling and lathe machines. I also learned a lot about 3D printing at the lab. The lab not only provided me with knowledge but also with key technical experience of comprehensive product development modeling-prototyping-improving design – manufacturing, which played a crucial role in getting selected for Internships and receiving a scholarship at the University of Birmingham. I affirm that my knowledge and ability of implementing 3D printing technology in product development has improved from beginner to developer level.

Observation 2:

Who I am:

I am Sricharan Nampalli pursuing M. Tech in the Department of Mechanical Engineering at Anurag University. My M. tech project is titled as "Reconstruction of Index Finger Bones". I am utilizing the facilities of CRDM (Centre for Research in Digital Manufacturing).

What I have learned from CRDM?

First, I studied 3D printing machines like FDM (fused deposition modeling) and SLA (stereolithography [Form 3B printer]). Next, modelled a solid model of index finger bones using Solidworks software, and the data (dimensions and shape) is extracted using X-ray images. After that, the simulation (static) is done using Ansys software and

mechanical properties added during simulation setup. The solid model is converted into .STL format using Cura software. In the end, the model is printed using FDM and SLA, printed in two types of printers to check the accuracy and the fine printing. This gave me a touch and feel of entire mechanism I have designed, that resulted in inputs in its development. Finally, the printed part is tested (tensile and static) and a final report is made. Each technology has its own advantages and limitations based on the budget of the printer and the resolution of the printing machines. I can realize that my proficiency level of implementing 3D printing technology has improved from beginner to proficient level as per rubric mentioned.

Observation 3:

Who I am:
This is Naseeruddin Ahmed, Research scholar, Department of Mechanical Engineering at Anurag University, Hyderabad, have opted the broad research area as Development and characterization of Hybrid polymer composite using Additive Manufacturing. The Anurag University, Hyderabad is facilitating with the CRDM (Center for Research in Digital Manufacturing) for conducting the research work of PhD and experimental works of the PG and UG students of Mechanical Engineering.

What are the facilities motivated me to do research at CRDM?
Now a days, as a part of Industry 4.0, all the manufacturing industries are turning towards the IOT (Internet of Things), to match the requirements of the manufacturing sector. The digital manufacturing is the upcoming technology, and can match with the industry 4.0. As manufacturing sector is very essential for any nation in its GDP, our honourable Prime Minister had introduced Make in India and Atma Nirbhar Bharat Schemes to encourage manufacturing at different scales. The Center for Research in Digital Manufacturing is facilitating range additive manufacturing equipment like FDM, SLA printers including 3D Scanner. These may help me in my research to carry out varied design of experiments as I would like to choose fused deposition modelling machine for additive manufacturing and the 3D scanner may also help in scanning the component made by conventional methods for copying and replicating, instead of searching for the machines somewhere else. I believe that these kinds of facilities in digital manufacturing have to be upgraded and conducting the faculty development programmes on hand practice workshops and trainings for the students. I believe that my insights about the technology has improved from beginner to developer level.

Observation 4:

Who I am:
I am Putta Bhavani pursuing under graduation in Mechanical Engineering in Anurag University. I am a part of Anurag Sat Mechanical Engineering department team and got

selected into the programme in my first year after clearing the exam conducted to join Anurag Sat. I have published a journal paper in the November, 2023. The paper focuses on the structure, thermal and vibrational analysis of a 1U CubeSat. First the 2D version of the component was designed which was extended to 3D and then I have done analysis using the software called ANSYS.

How CRDM [Center for Research in Design and Manufacturing Engineering] was Useful?

TABLE II
EXPERIMENTAL TEST CASES WITH OUTCOME

Observation	Name	Designation	Outcome
1	Mr. Akshay	4th Year UG Major Project Student	Experienced hands on approach in 3D printing Technology. Higher education with stipend € 800/month.
2	Mr. Hari Charan	PG Student	Underwent training in 3D printing technology and that led to interest in Bio 3D printing Research Collaboration with reputed Hospital towards his dream to become an entrepreneur and in the process of registering a firm .
3	Mr. Nasiruddin	PhD Research Scholar & Sr Lecturer in Govt Polytechnic College	Got exposed to 3D printing technology and identified research gaps. Progress in implementing the 3D printing Technology for outcome-based learning for diploma students.
4	Ms. Bhavani	2nd Year UG Student. Anurag Sat Student Member	Gained knowledge on using 3D printing technology for prototyping. Scopus Indexed Journal & Opportunity at ISRO

We have taken the help of the CRDM lab in our university. We basically, made a 3D printed model at CRDM. The model made was of a 1U CubeSat Structure of the dimensions same as that of what we have analyzed with ANSYS. I could get a feel of the product we modeled by 3D printing it. This gave us more insights in prototyping. Center for research in Digital Manufacturing is the one of the aspects that led me to get an

ISRO internship Opportunity. I can identify that my knowledge and skill of implementing 3D printing technology has improved from beginner to proficient level.

V. CONCLUSION

The goal of this study was to investigate the present educational system in India and throw light on effective learning that can happen by utilizing contemporary digital manufacturing techniques like 3-D printing in classroom instruction or practical exposure to it rather the conventional and traditional methods. For this, qualitative study was conducted on a sample of students and a 3D printing facility at Anurag University, an Indian host for research in digital manufacturing. The conclusions that were reached and the findings that were provided in the previous section were solely based on personal interpretation of the students' initial observations. On a national level, it may be relevant in the same situation. Research has also shown that respondents are inspired and optimistic about the future in this ground-breaking industry and happy with how well-informed people and institutions are becoming about this digital manufacturing technology. Anyhow, the findings of this study, if implied will be advantageous for educational institutions. Nobody will lack the resources necessary to achieve their goals as long as educational institutions continue to embrace this technology. To put it briefly, engineering universities that have 3D printers on their property are turning new concepts into reality. They also have skilled teachers and train their specialists to create 3D labs in their institutions. The results will be extremely beneficial to educational institutions, students, researchers, and society at large. A futuristic strategy to revolutionize the educational system is the last step. The area of education is expanding, and educators may create effective policies. I strongly believe, presented study act as a stepping stone towards enhancing the digital era in Indian education system.

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