Z ALPHA MULTIDISCIPLINARY RESEARCH JOURNAL

e-ISSN: 3139-0846
Research Article
Received on: 18-May-2026
Revised on: 12-Jun-2026
Accepted on: 14-Jun-2026
Published Online: 23-Jun-2026
Vol. 2, Issue 1, 2026, 7-13.

Design and Development of Customized Coasters Using 3D Printing Technology

Prakash Balan Ganesan[a]* | Suresh Reina Govindaraj[a] | Prakash Pandian[a] | Vinoth Sekar[a] | Dhushyanth Ajay Saravanan[a]

[a] UG Student, Department of Mechanical Engineering, Mookambigai College of Engineering, Pudukkottai, Tamil Nadu, India.
***** Author for Correspondence Email: gprakashbalanmech@gmail.com

Abstract

This research investigates the development and production of personalized utility items through additive manufacturing techniques. Building on previous work with personalized coasters, the project was expanded to include practical items for educational institutions, such as a chalk piece and duster holder, ID card holder, and classroom name board. The designs were created using CAD tools including Fusion 360, Tinker CAD, and SolidWorks, each supporting different stages of the design process. The designed models were fabricated through optimized printing settings to achieve improved accuracy and operational efficiency. Lean production strategies were incorporated to minimize resource consumption, shorten fabrication duration, and enhance process performance. The results show that 3D printing provides a cost-effective and flexible solution for producing customized, functional products in educational settings. This study highlights the potential of additive manufacturing as an innovative and scalable alternative to traditional production methods.

Keywords: 3D Printing, CAD Modeling, Lean Manufacturing, Sustainability, Educational Products.

1. Introduction

Additive manufacturing (AM), commonly referred to as 3D printing, has emerged as an important manufacturing technology that enables the fabrication of complex geometries directly from digital models with minimal material wastage. The environmental benefits of polymer-based additive manufacturing have been highlighted by Alvarez & Martinez (2021), while Das and Chattopadhyay (2021) emphasized the role of CAD/CAM integration in improving digital product development and manufacturing efficiency. Owing to these advantages, AM has gained increasing acceptance across several engineering sectors. The industrial adoption of additive manufacturing continues to expand into diverse application areas. Kaur & Singh (2021) demonstrated its growing importance in the automotive sector through rapid product development and lightweight component fabrication. Patel & Shah (2021) reviewed its applications in electronics manufacturing, whereas Dissanayake & Rashid (2022) discussed its role in biomedical engineering and material selection challenges. Similarly, Martinez & Perez (2022) reported successful applications of 3D printing in customized medical prosthetics, highlighting its capability for patient-specific manufacturing. Hong & Lee (2021) also demonstrated that additive manufacturing provides significant advantages over conventional manufacturing for rapid tooling and customized low-volume production, further highlighting its industrial versatility.

Among the available AM techniques, Fused Deposition Modeling (FDM) remains one of the most widely used because of its affordability, operational simplicity, and compatibility with polymeric materials. Aasim & Ali (2023) demonstrated that infill pattern selection significantly influences the mechanical properties of FDM components. Ali & Khan (2024) optimized process parameters to improve surface quality through the Taguchi method, while Chen & Xiao (2024) investigated the influence of nozzle diameter on tensile behaviour. El-Taweel (2024) reported that build orientation directly affects fatigue life, and Nasrollahi & Baniassadi (2023) showed that raster angle significantly influences fatigue resistance in printed structures. Process optimization has become an active area of research for improving print quality and manufacturing reliability. Gupta & Jain (2023) optimized ABS printing parameters using response surface methodology, whereas Kumar and Gupta (2024) analysed the effect of infill density on impact strength. Hsu & Wu (2022) examined the influence of print speed on composite performance, while Cheng & Lin (2023) proposed a digital twin framework for quality improvement. Li & Zhao (2023) introduced machine-learning-based parameter optimization techniques, and Qin & Yang (2023) demonstrated artificial intelligence approaches for quality control in additive manufacturing. The influence of surrounding environmental conditions during FDM processing was also investigated by Mao & Zheng (2024).

Material development and sustainability have received increasing attention in recent years. Evans & Williams (2022) discussed sustainable process selection strategies for additive manufacturing, whereas Feng & Wang (2023) developed environmentally friendly PLA bio-composites for printing applications. He & Zhang (2024) explored the integration of sustainable materials into modern AM systems, and Singh & Kumar (2022) evaluated the environmental impacts associated with polymer 3D printing processes. Gao & Huang (2022) investigated microstructure evolution and property control in advanced printed materials, providing further insight into performance enhancement.

The application of lean manufacturing principles has further strengthened the efficiency of additive manufacturing systems. Fleischmann & Schmidt (2021) demonstrated the successful implementation of lean concepts within AM environments, while Bacchetti & Biral (2022) analysed the economic feasibility of additive manufacturing for small and medium-scale industries. Liang & Hao (2022) presented topology optimization methods for lightweight structural design, contributing to improved material efficiency and performance. Continuous material innovation has expanded the functional capabilities of additive manufacturing. Behera & Singh (2023) investigated the mechanical characterization of hybrid composite materials fabricated through 3D printing. Jafari & Mohammadi (2023) reviewed the development of nanomaterial-reinforced printable polymers for enhanced engineering applications. Wijaya (2026) demonstrated the design and functional optimization of customized coasters using PETG-based additive manufacturing, illustrating the feasibility of producing personalized consumer products. Furthermore, Park & Choi (2024) highlighted the effectiveness of user-centred 3D printing applications in educational environments and their contribution to practical learning and innovation.

Although significant progress has been achieved in additive manufacturing technologies, comparatively limited attention has been given to the fabrication of simple institutional utility products through an integrated approach involving CAD modelling, FDM-based 3D printing, and lean manufacturing principles. Products such as customized chalk piece and duster holders, classroom name boards, and ID-card holders require flexibility, rapid production, and economical fabrication while maintaining acceptable quality and functionality. Therefore, the present study focuses on the design, development, and fabrication of customized educational utility products using 3D printing technology, with emphasis on process efficiency, sustainable material utilization, reduced manufacturing waste, and practical implementation in educational institutions.

2. Materials and Methods

2.1. Design of Coasters

The development of personalized coasters was performed with the help of computer-aided design (CAD) tools, and the CAD models of the Chalk Piece & Duster Holder, Nameplate, and ID-Card Holder are illustrated in Figures 1, 3, and 5. Multiple coaster variations were designed according to user requirements, incorporating personalized text, symbols, and geometric features. The coaster dimensions were maintained within standard limits to suit commonly used cup sizes, generally between 80 mm and 100 mm in diameter with a thickness ranging from 4–6 mm. The completed CAD models were then converted into STL files for use in the slicing stage of the printing workflow.

2.2. Material Selection and 3D Printing Process

Choosing suitable materials and operating conditions is essential for achieving reliable performance, strength, and print quality in fabricated components. In this study, materials were chosen based on factors such as printability, cost-effectiveness, environmental impact, and mechanical performance. The parameters and specifications are mentioned in Table 1. Additive Manufacturing technology, specifically the fused deposition Modeling (FDM) approach by FlashForge Printer, was used to carry out the fabrication process.

Model slicing, parameter setting, printing, and post-processing were all part of the workflow. STL files were converted into G-code, which contains instructions for the 3D printer, using slicing software like FlashPrint. The experimental data, including material, print time, and estimated material consumption, is summarized in Table 2. Process variables like layer height, infill density, printing speed, and nozzle temperature were carefully adjusted to produce high-quality prints with less material waste.

Because of its biodegradability, usability, and suitability for desktop 3D printing applications, polylactic acid (PLA) was the printing material of choice. PLA is a sustainable product development option because it is an eco-friendly thermoplastic made from renewable resources like corn starch. In addition, Acrylonitrile Butadiene Styrene (ABS) was considered for comparative analysis due to its higher strength and durability. However, ABS requires higher processing temperatures and emits fumes during printing, making PLA a more practical option for educational and indoor environments. The selection of materials was based on balancing performance characteristics with sustainability considerations, ensuring that the final products are both functional and environmentally responsible.

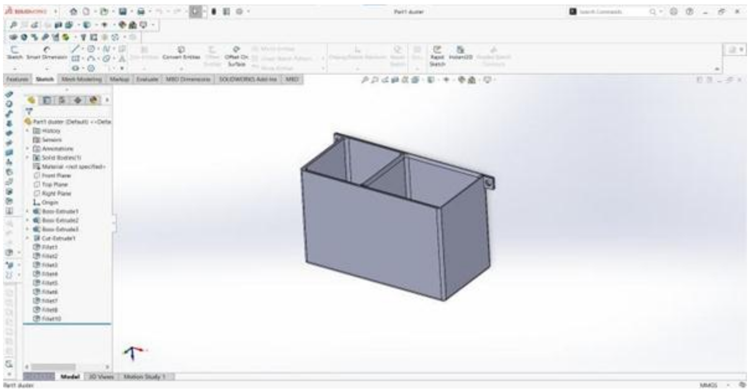

Figure 1 CAD model of the customized chalk piece and duster holder designed using SolidWorks for Fabrication using FDM 3D Printing technology.

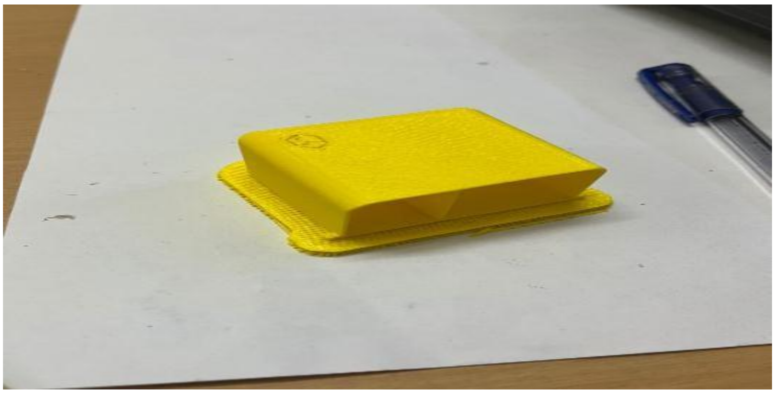

Figure 2 3D printed prototype of the customized chalk piece and duster holder fabricated using PLA material through FDM technology, demonstrating the successful conversion of the CAD design into a functional physical model.

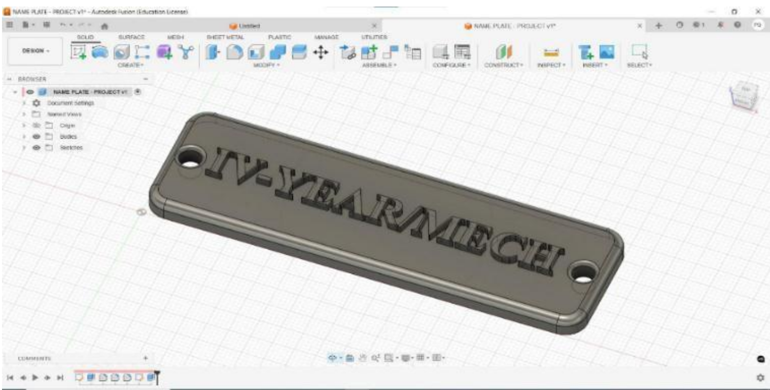

Figure 3 CAD model of a customized classroom Nameplate designed using Autodesk Fusion 360, featuring engraved text and mounting holes for easy installation.

Figure 4 3D printed prototype of the customized Nameplate fabricated using PLA material through FDM technology, demonstrating the successful production of a personalized component from the developed CAD model.

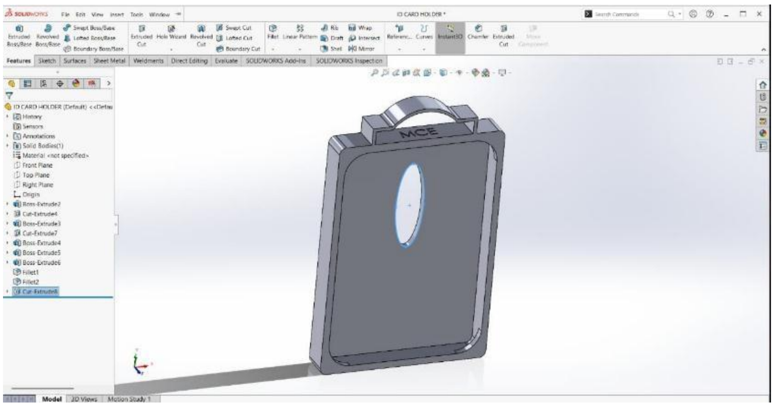

Figure 5 CAD model of a customized ID-Card designed using Solidworks for fabrication using FDM 3D printing technology.

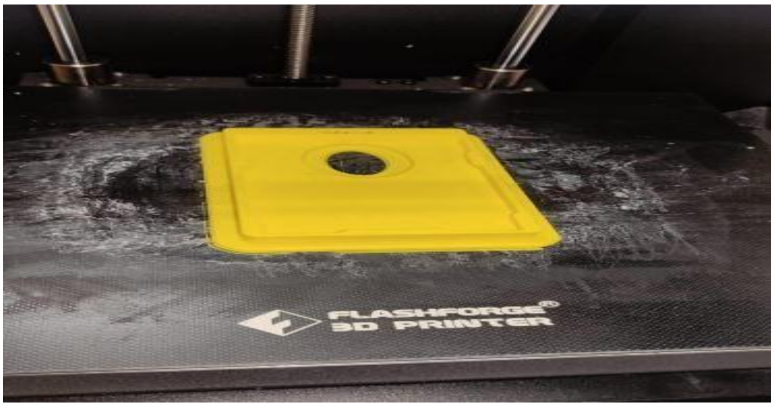

Figure 6 3D printed prototype of the customized ID-Card fabricated using PLA material FDM technology, demonstrating the successful transformation of the CAD design into a functional and personalized physical component.

Table 1 3D Printing Process Parameters (Optimized Settings)

Parameters	Specifications
Printer	FlashForge FDM-based 3D printer
Slicing Software	FlashPrint (STL to GX conversion)
Material	FlashForge-PLA
Layer Height	0.18 mm
Infill Density	15%
Print Speed	50 mm/s
Travel Speed	80 mm/s
Extruder Temperature	195 °C
Platform Temperature	60 °C

Table 2 Experimental Data Summary

Product	Material	Print Time (Hrs.)	Product Weight (g)	Estimated Material (m)
Chalk Piece & Duster Holder	PLA	1.15	11.79	3.95
Name Plate	PLA	2.23	28.3	9.49
ID-Card Holder	PLA	2.1	22.86	7.66

3. Results and Discussion

The outcomes of the design and production of personalized coasters and institutional utility products show how Additive Manufacturing can be used to create useful, affordable, and customizable products. The results are examined in relation to structural performance, print quality, material utilization, and process efficiency. Products with adequate strength, durability, and dimensional accuracy were successfully developed through the integration of CAD Modeling and optimized printing parameters. Additionally, the implementation of Lean Manufacturing principles enhanced overall production efficiency and reduced waste.

3.1. Fabrication Outcomes and Print Quality

The manufactured coasters and utility items, such as the name board, ID card holder, and chalk holder, showed good dimensional accuracy and surface finish (Figures 2, 4, & 6). The layer-by-layer deposition process caused some prints to have minor surface irregularities, but these were reduced by parameter optimization and post-processing methods like sanding.

The use of PLA material resulted in smooth prints with consistent layer adhesion. The dimensional deviations were found to be within acceptable limits (±0.5 mm), indicating the reliability of the design and fabrication process. Complex features such as engraved text and logos were successfully reproduced, demonstrating the capability of 3D printing for customization.

3.2. Material Utilization and Process Efficiency

The efficiency of the manufacturing process was assessed by analyzing the production time and material consumption. Because material is only deposited where needed, the results show that 3D printing greatly reduces material waste when compared to traditional manufacturing techniques. Depending on the complexity of the design, printing a coaster typically took 1.5 to 2 hours and required 20 to 30 grams of PLA. The application of optimized slicing parameters helped reduce both print time and material usage without compromising product quality. The adoption of Lean Manufacturing principles, such as minimizing excess material usage and reducing idle time, further enhanced production efficiency. This demonstrates the suitability of 3D printing for small-scale and on-demand manufacturing.

3.2.1. Comparison with Traditional Manufacturing

A comparative analysis between 3D printing and conventional manufacturing methods highlights several advantages of Additive Manufacturing. Traditional methods such as injection Molding involve high initial tooling costs and are not suitable for low-volume or customized production. In contrast, 3D printing eliminates the need for molds and enables rapid design modifications. The production time for customized items is significantly reduced, and there is minimal material wastage. However, traditional methods may still be more efficient for mass production due to higher production rates once tooling is established. Overall, 3D printing is more advantageous for customized, low-volume production, particularly in educational and institutional settings where flexibility and cost-effectiveness are essential.

3.3. Sustainability and Practical Implications

The study demonstrates that 3D printing contributes to sustainability through efficient material utilization and reduced waste generation. The use of PLA, a biodegradable material, further enhances the environmental benefits of the process. Practically speaking, this strategy is ideal for educational institutions because it can create personalized goods on demand. It enables cost-effective production of utility items while supporting innovation and skill development. Additionally, the integration of Lean Manufacturing ensures that the process remains efficient, scalable, and aligned with modern manufacturing practices.

4. Conclusions

The current study successfully demonstrated how additive manufacturing techniques can be used to create customized utility products. The creation of useful, affordable, and adaptable products appropriate for educational settings was made possible by the combination of CAD Modeling and additive manufacturing. The findings demonstrate that 3D printing is very successful for customized and low-volume production, providing notable benefits over conventional manufacturing techniques in terms of flexibility, decreased material waste, and quicker production times. The application of lean manufacturing principles further improved process efficiency by minimizing unnecessary material usage and optimizing the production workflow. The use of PLA material supports sustainability due to its biodegradable nature and ease of processing, making it suitable for indoor and educational applications. The successful fabrication of products such as coasters, chalk holder, ID card holder, and nameplate demonstrates the practical applicability of additive manufacturing in institutional settings. However, some drawbacks were noted, such as a moderate production speed and small surface imperfections, which might necessitate post-processing for a better finish. Future research can concentrate on investigating cutting-edge materials, enhancing print quality, and broadening the scope of applications.

Acknowledgment

AI-based chat assistance was used solely for grammar correction improvement in this paper. This research ideas, analysis, and conclusions presented in this work are entirely the author's original contribution.

Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare no conflicts of interest.

Funding

This research did not receive any financial support.

References

1. Wijaya, F. (2026). Design and functional optimization of a multi-feature coaster using PETG-based additive manufacturing. Dinamika Teknik Mesin, 16(1), 47–56.
2. Aasim, M., & Ali, S. (2023). Influence of infill pattern on mechanical properties of FDM 3D-printed parts. Journal of Manufacturing Processes, 83, 452–460.
3. Ali, M., & Khan, A. (2024). Optimization of 3D printing parameters for enhanced surface quality using Taguchi method. Journal of Materials Processing Technology, 306, 117731.
4. Alvarez, J., & Martinez, R. (2021). Life cycle assessment of 3D printed polymer components. *Journal of Cleaner Production, 278*, 123789.
5. Bacchetti, R., & Biral, F. (2022). Economic feasibility of additive manufacturing in SMEs. *Journal of Manufacturing Technology Management, 33*(4), 912–930.
6. Behera, A. K., & Singh, D. (2023). Mechanical characterization of hybrid composite materials via 3D printing. *Composite Structures, 300*, 116149.
7. Cheng, M. Y., & Lin, S. Y. (2023). Digital twin approach for improving 3D printing quality control. *Robotics and Computer-Integrated Manufacturing, 78*, 102310.
8. Chen, L., & Xiao, H. (2024). Effect of nozzle diameter on tensile behavior of FDM printed specimens. *Materials & Design, 220*, 110902.
9. Das, S., & Chattopadhyay, A. (2021). CAD/CAM integration for streamlined 3D product development. *Computer-Aided Design and Applications, 18*(6), 1075–1086.
10. Dissanayake, N., & Rashid, A. M. (2022). Additive manufacturing for biomedical applications: Materials and challenges. *Biomedical Engineering Journal, 13*(3), 211–225.
11. El-Taweel, T. A. (2024). Impact of build orientation on fatigue life of 3D printed parts. *International Journal of Fatigue, 156*, 106610.
12. Evans, J. R., & Williams, D. (2022). Sustainable process selection for additive manufacturing. *Journal of Industrial Ecology, 26*(5), 1224–1241.

13. Feng, P., & Wang, Q. (2023). PLA bio composite development for eco-friendly 3D printing. *Polymers & Polymer Composites, 31*(2), 145–156.
14. Fleischmann, P., & Schmidt, H. (2021). Lean principles in additive manufacturing implementation. *International Journal of Production Research, 59*(11), 3305–3322.
15. Gao, N., & Huang, Y. (2022). Microstructure evolution and properties control in 3D printed metals. *Materials Characterization, 185*, 111789.
16. Gupta, R., & Jain, V. K. (2023). Process parameter optimization for ABS 3D printing via response surface methodology. *Journal of Materials Research and Technology, 22*, 4162–4174.
17. He, Y., & Zhang, Z. (2024). Integration of sustainable materials in additive manufacturing. *Sustainable Materials and Technologies, 32*, e00409.
18. Hong, S., & Lee, J. (2021). Comparison of traditional vs. additive manufacturing for rapid tooling. *Journal of Manufacturing Science and Engineering, 143*(10), 101006.
19. Hsu, C. H., & Wu, Y. T. (2022). Influence of print speed on mechanical performance of 3D printed composites. *Materials Today Communications, 32*, 103166.
20. Jafari, R., & Mohammadi, M. (2023). 3D printable polymers reinforced with nanomaterials: A review. *Polymer Composites, 44*(10), 3839–3852.
21. Kaur, G., & Singh, R. (2021). Application of additive manufacturing in automotive sector. *Journal of Engineering and Technology Management, 60*, 101632.
22. Kumar, S., & Gupta, A. (2024). Effect of infill density on impact strength of 3D printed parts. *Materials Science and Engineering A, 834*, 144475.
23. Li, F., & Zhao, X. (2023). Parametric study of 3D printing quality improvement using machine learning. *Journal of Manufacturing Systems, 68*, 103–114.
24. Liang, Y., & Hao, Y. (2022). Topology optimization in additive manufacturing for lightweight design. *Structural and Multidisciplinary Optimization, 66*(3), 1–15.
25. Mao, W., & Zheng, K. (2024). Influence of environmental conditions on fused deposition Modelling. *Journal of Thermal Analysis and Calorimetry, 147*(12), 5431–5443.
26. Martinez, J. L., & Perez, A. (2022). Application of 3D printing in medical prosthetics production. *Journal of Prosthetics and Orthotics, 34*(2), 112–120.
27. Nasrollahi, A., & Baniassadi, M. (2023). Influence of raster angle on fatigue resistance of 3D printed parts. *Fatigue and Fracture of Engineering Materials & Structures, 46*(6), 1632–1645.
28. Patel, H., & Shah, D. (2021). New review on additive manufacturing for electronics. *Electronics, 10*(10), 1214.
29. Park, J., & Choi, Y. (2024). User-centered design applications with 3D printing in education. *Education and Information Technologies, 29*(2), 2457–2478.
30. Qin, T., & Yang, L. (2023). Quality control in additive manufacturing using AI approaches. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 37*(4), 367–380.
31. Singh, P., & Kumar, R. (2022). Environmental impacts of polymer 3D printing: Air quality study. *Environmental Impact Assessment Review, 94*, 106789.