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Establishing a University-Based Center for Design and 3D Printing Services: A Practical Innovation and Learning Model

Tala N. Alharbi[1], Layan H. Bjaili[2], Retal E. Zahran[3], Faisal J. Alzahrani [4]
[1]King Abdulaziz University, Faculty of Engineering, Saudi Arabia, Rabigh; Talharbi0271@stu.kau.edu.sa
[2]King Abdulaziz University, Faculty of Engineering, Saudi Arabia, Rabigh; lbjaili@stu.kau.edu.sa
[3]King Abdulaziz University, Faculty of Engineering, Saudi Arabia, Rabigh; rzahran0٠05@stu.kau.edu.sa
[4]King Abdulaziz University, Faculty of Engineering, Saudi Arabia, Rabigh; fjsalzahrani@kau.edu.sa

Abstract. In response to the increasing demand for practical innovation platforms in higher education, this paper presents a conceptual and implementation framework for establishing a university-based center dedicated to design, modeling, and 3D printing services. The proposed center, proposed for development within the College of Engineering, aims to serve both students and external stakeholders by integrating academic learning with real-world applications. Equipped with professional tools such as SolidWorks and Fused Filament Fabrication (FFF) 3D printing technology, the center is designed to support engineering education while encouraging entrepreneurial thinking and hands-on experience.

For years, universities have sought to strike a balance between academic ideals and the need for practical innovation. Success has often been mixed. This proposal examines one initiative: a new center in the College of Engineering dedicated to design and 3D printing. The center aims to blend classroom learning with real-world industry experience. Where both mistakes and successes are valuable learning experiences. The goal is to involve students and outside partners, such as small businesses or individual entrepreneurs, who can bring real challenges that go beyond what textbooks cover.

The technical foundation relies on SolidWorks and fused filament fabrication printers for modeling and printing. These choices reflect not an obsession with the most sophisticated technology but a recognition of reliability and affordability. Initial efforts show excitement but also highlight areas where technical skills need improvement. The business model is still being developed and is meant to guide cost recovery while supporting educational goals. Universities should function as incubators for such initiatives, integrating creativity and entrepreneurship into students' daily academic activities. Iterative design modifications and failed printed products are the most common challenges in additive manufacturing. These challenges foster practical competencies relevant to professional environments. Also, such experiential learning opportunities will facilitate the transition from a theoretical mindset to the dynamic conditions that lead to entrepreneurial ventures.

Keywords: Design, 3D Printing, Student Prototyping, Digital Manufacturing, Entrepreneurship.

1. Introduction

Additive manufacturing, more commonly called 3D printing, has been discussed for decades as a technology with the potential to change many industries. It began in the 1980s, but only in the last ten or fifteen years has it moved beyond specialized labs and into places like classrooms, hospitals,

and even home workshops. Additive manufacturing builds objects by adding material layer by layer instead of removing material from a solid block. This approach makes it possible to create shapes with hollow spaces, smooth curves, or lattice structures that were difficult to make with older methods. Scholars have highlighted both the exciting possibilities and the current challenges, especially when it comes to material strength and cost. (Zhou et al., 2024). The importance of 3D printing lies in the ability to produce parts with complex geometry compared to conventional manufacturing methods (Kanishka & Acherjee, 2023). In higher education, the real value of this technology comes from its impact on teaching and learning. Studies show that when students participate in designing, slicing, printing, and troubleshooting, they gain a much deeper understanding of design, materials, and production limitations. However, access to these tools is limited. Some universities have advanced labs, while others offer only a few desktop printers. A well-designed center can bridge this gap by providing a space that is both (Staribratov & Manolova, 2024).
Establishing a 3D printing center at the university would benefit students, faculty, and outside partners. This center could become a hub for students, scholars, and entrepreneurs from different disciplines to collaborate on innovative ideas. With a range of 3D printers and digital tools, users can quickly test and refine their designs, helping to accelerate innovation and research (Zhou et al., 2024). Offering structured services to industry partners, startups, and other external users can help generate revenue and support the center's financial stability. These centers also help develop the workforce by giving students practical training and preparing them for jobs in the fast-growing field of additive manufacturing.(Cossette et al., 2022). This paper explores why it is important to bring additive manufacturing into universities. Such a center would encourage research, education, and collaboration with industry, helping financial sustainability.

2. Materials and Methods

This paper outlines the proposed design, infrastructure, and operational protocols for a university-affiliated 3D printing center, designed to serve students, faculty, and approved external stakeholders. While the center has not yet been physically implemented, the methodology described herein offers sufficient granularity for replication by academic institutions or innovation hubs. All software, equipment, and materials referenced are commercially available in the Kingdom of Saudi Arabia as of the second quarter of 2025. The design is modeled on best practices from digital fabrication labs and optimized print farm configurations (Lipson & Kurman, 2013).

2.1. Proposed Print Farm Structure

The proposed center will be based on a modular FDM (Fused Deposition Modeling) print farm arranged in a compact and scalable configuration. The facility will be divided into key zones:

● CAD and Slicing Zone: Equipped with high-performance computers for 3D modeling and G-code generation.

● Printing Farm: Houses 15 FDM printers installed on heat-resistant, ventilated workstations with power management systems.

● Post-Processing Area: Dedicated to support removal, sanding, finishing, and visual inspection.

● Material and Tool Storage: Climate-controlled cabinets designed to minimize filament degradation due to humidity.

The layout is based on lean manufacturing principles and adheres to safety and environmental standards specified by the Saudi Civil Defense and the Saudi Standards, Metrology and Quality Organization (SASO).

2.2. Equipment and Consumables

All equipment was selected based on local market availability, performance reliability, and cost-efficiency. Procurement will be through regional vendors such as 3DME Saudi, Nozol, and other authorized distributors. The complete breakdown of equipment, specifications, and costs is provided in Table 1.

Table 1. Equipment and Consumables

Component	Model / Specification	Unit Price (SAR)	Qty	Total (SAR)
Entry-Level FDM Printers	Creality Ender 3 V3 SE	950	10	9,500
Mid-Range FDM Printers	Prusa i3 MK4	2,700	5	13,500
PLA Filament (1kg)	Local vendor, 1.75mm ±0.03mm	55	150	8,250
Slicing Workstations	Ryzen 7, RTX 4060, 32GB RAM	4,200	5	21,000
Filtration Hoods	Carbon-based, ductless system	4,800	2	9,600
Remote Monitoring System	OctoPrint + Raspberry Pi 4B	600	10	6,000
Post-Processing Tools	Sandpaper, epoxy, scrapers	Lump sum	-	2,000

Estimated Total: SAR 69,850 (~USD 18,600)

The primary material is Polylactic Acid (PLA), selected for its biodegradability, dimensional stability, and low emissions during printing (Ngo et al., 2018). PETG and Thermoplastic Polyurethane (TPU) are proposed for future use after the operator has received extended training. Filament will be stored in airtight containers with silica gel to combat humidity-induced degradation, a key concern in Gulf climates (Ngo et al., 2018).

2.3. Software Tools and File Preparation Protocol

The center will utilize SolidWorks 2023 EDU for parametric modeling and Ultimaker Cura 5.4 for slicing tasks. Cura is an example of open-source slicing software commonly used in FDM workflows (Vaezi, Seitz, & Yang, 2012). Ultimaker Cura was selected based on studies that show its widespread use in FDM systems and its influence on G-code and printing outcomes (Bryła & Martowicz, 2021). Default slicing parameters include:

- Layer height: 0.2 mm
- Infill: 20% (Grid/Gyroid)
- Nozzle diameter: 0.4 mm
- Speed: 60 mm/s (PLA), 40 mm/s (PETG)
- Supports: Enabled for overhangs > 45°

- Bed adhesion: Skirt (3 lines)

Slicing profiles will be centrally configured to standardize print quality and minimize failure rates. Each printer will be equipped with OctoPrint on Raspberry Pi 4B for real-time job tracking and queue automation (Kakade, Mulay, & Patil, 2022).

2.4. Operational Model and Staffing Plan

The center will be run by trained student operators and overseen by faculty supervisors, promoting experiential learning while ensuring high operational standards.

- Student Operators: 5–7 per term, trained in slicing, printer maintenance, troubleshooting, and safety protocols.
- Faculty Supervisors: Responsible for oversight, approval of advanced jobs, and mentorship.

All users must complete a certification workshop, which covers:

- Printer operation and maintenance
- Cura slicing and SolidWorks basics
- Safety protocols in line with EHS standards

Upon certification, users gain access to the portal, where they can submit jobs, check material usage, and monitor queue status.

2.5. Workflow and Submission Process

A five-stage workflow standardizes the submission-to-delivery process:

1. File Submission: STL/OBJ files uploaded via the internal job portal.
2. Review and Approval: Operators assess print feasibility and calculate resource estimates.
3. Slicing and Assignment: Jobs are sliced and routed to the next available machine.
4. Printing and Monitoring: Supervised execution with live OctoPrint tracking.
5. Post-Processing and Delivery: Removal of supports, final inspection, and job release.

Print metrics, including failure rate, duration, and filament usage, are logged to aid predictive maintenance and resource planning.

2.6. Pricing Structure and Access Model

To ensure long-term sustainability, a tiered pricing structure is proposed, as detailed in Table 2.

Table 2. Pricing Structure and Access Model

User Type	Material Cost (SAR/g)	Machine Time (SAR/hr)	Notes
Students	0.00	0.00	Covered under academic quota
Faculty	0.10	5.00	Research cost-recovery model
External Users	0.20	15.00	Paid access via institutional MOU

All payments will be handled via the university's finance system. External clients must sign service agreements and adhere to the center's operational guidelines.

2.7. Data Transparency and Implementation Notes

All price data, vendors, and models were validated through local suppliers as of the second quarter of 2025. STL slicing profiles and training templates will be published on GitHub for academic reuse after the pilot phase.

Files to be made publicly available:

- Cura slicing profiles (.curaprofile)
- OctoPrint configuration (yaml)
- User training manual (PDF)

Restrictions: No biological, chemical, or export-controlled materials are permitted. Institutional software licenses (e.g., SolidWorks) will not be redistributed.

3. Discussion

The establishment of a university-based 3D printing center represents a strategic initiative that must be evaluated through multiple dimensions. This discussion examines the proposal through four critical lenses: validation from local academic experience, strategic positioning within the educational landscape, evidence of commercial viability, and pragmatic addressing of sustainability challenges.

3.1. Operational Validation through Academic Experience

The conceptual framework for this center finds strong support in a structured academic initiative involving 43 engineering students at the Rabigh campus. This experience, while educational in purpose, effectively simulated centralized operations by producing over 380 components across 18 diverse projects spanning mechanical devices, functional tools, and complex assemblies. The scale of output requiring more than 250 G code files and 300 hours of print time was successfully managed through coordinated scheduling and workflow optimization, demonstrating the efficiency of a centralized model.

Beyond quantitative metrics, the experience revealed profound educational benefits. Students developed comprehensive skills in design thinking, technical troubleshooting, and project management competencies increasingly demanded by modern industry (Staribratov & Manolova, 2024). The diversity of successful projects, from practical engineering solutions to creative designs, underscores the potential for cross disciplinary application and confirms substantial latent demand for accessible digital manufacturing resources within the student population.

3.2. Strategic Positioning in the Academic Ecosystem

When benchmarked against existing models, the proposed center occupies a distinctive niche that complements rather than replicates available facilities. The KAUST Prototyping Core Lab excels in advanced research but focuses less on structured undergraduate integration (King Abdullah University of Science and Technology, n.d.). Regionally, Abu Dhabi University's 3D Concrete Printing Lab demonstrates specialized excellence but its narrow construction focus limits broader applicability (Abu Dhabi University, 2023). Globally, institutions like the University of Nottingham's Centre for Additive Manufacturing prioritize postgraduate research over undergraduate accessibility (University of Nottingham, n.d.).

This analysis reveals the proposed center's unique value proposition: a hybrid model balancing hands on undergraduate education with research and external collaboration capabilities. This positioning addresses a clear gap in the regional landscape, creating an environment where learning and innovation can coexist within a sustainable framework.

3.3. Commercial Precedents and Economic Sustainability

The financial viability of such a center is strongly supported by established commercial practices. Service providers like Shapeways and Materialise have built sustainable businesses on service bureau models, with the latter exceeding EUR 200 million in annual revenue (Materialise, 2023; Shapeways, 2023). These operations achieve high equipment utilization rates often surpassing 1,200 productive hours per printer annually through advanced queue management and real time monitoring systems that ensure consistent throughput while minimizing downtime (Kakade et al., 2022). The sustainability of these operations is further reinforced by diversified revenue models, where firms combine B2B contracts with B2C services, mitigating market fluctuations (Lipson & Kurman, 2013). The commercial scale and technological focus of key industry players are summarized in Table 3.

Table 3. Industry Evidence of 3D Printing Firms and Patent Holders

Company / Firm	Location	Core Technology	Annual Revenue (Approx.)
Shapeways	USA / Netherlands	FDM, SLS service bureau	USD 30M (2022)
Materialise NV	Belgium	SLA, SLS, medical printing	EUR 200M+ (2022)
Proto21	Dubai, UAE	FDM, resin printing	Not public
3DME	Saudi Arabia	FDM	Not public
3D Systems	USA	SLA, SLS	USD 540M (2023)
HP Inc.	USA	Multi Jet Fusion (MJF)	Multi-billion (segment)

As illustrated in Table 3, the success of regional firms like Proto21 in Dubai and 3DME in Saudi Arabia further confirms local market potential for additive manufacturing solutions. Furthermore, the intellectual property portfolios of established industry leaders illustrate the innovative potential of additive manufacturing. Stratasys holds the original patent for Fused Deposition Modeling (FDM), one of the most widely adopted techniques worldwide (Stratasys, 2023). Similarly, 3D Systems has secured thousands of patents in stereolithography (SLA) and selective laser sintering (SLS), while HP has registered patents for its Multi Jet Fusion (MJF) technology. This evidence suggests that a university-based center could achieve similar outcomes by fostering entrepreneurship, generating revenue through external collaborations, and supporting patentable innovation.

3.4. Implementation Challenges and Mitigation Frameworks

Long term success requires addressing several interconnected challenges. Technological obsolescence presents a persistent concern, as rapid advancements in additive manufacturing could quickly diminish the relevance of initial equipment investments without phased upgrade strategies (Li et al., 2025). Financial sustainability depends on developing realistic pricing models that account for frequently overlooked costs including equipment depreciation, maintenance, and operational labor factors often underestimated in academic settings (Ivkić et al., 2025).

Operational challenges include maintaining equipment reliability amid projected heavy usage, particularly concerning given potential limitations in local technical support infrastructure. Evidence indicates that insufficient preventive maintenance and lack of structured operator training frequently undermine service continuity (3DHEALS, 2023). Additionally, resource efficiency and environmental considerations must be integrated into planning, as energy intensive processes and material waste could compromise both economic and environmental sustainability (Liu et al., 2023). Proactive mitigation strategies should include a technology refreshment plan, tiered pricing balancing accessibility with cost recovery, rigorous maintenance protocols, and comprehensive operator training. These approaches would significantly enhance the center's resilience and long term impact while ensuring it remains a durable and sustainable innovation hub.

3.5. Conclusive Synthesis

The analysis confirms the center's strategic value through multiple converging lines of evidence. The academic experience demonstrates operational feasibility and educational impact, while benchmarking reveals a unique positioning within the regional ecosystem. Commercial precedents underscore economic viability, and identified challenges can be managed through deliberate strategies. The center brings together education, innovation, and industry partnerships to help achieve national development goals. Although setting it up will require close attention to technology changes and funding, the long-term benefits make it a worthwhile investment for preparing graduates and supporting new businesses.

4. Conclusion

This paper has explained all aspects of creating this center. It showed how students, faculty, and outside partners can come together to design, prototype, and solve problems with 3D printing technology. The proposed 3D printing center is more than a place to make things; it supports innovation, education, and national growth. With access to a variety of AM technologies like FDM, users can create complex designs and find solutions in many areas. The center also supports entrepreneurs, industry partners, and the community by helping to build strong connections between academia and industry.

Rabigh engineering students ran an educational pilot that showed a center like this can work well. Their hands-on experience demonstrated how a university 3D printing hub can enhance student engagement, foster creative thinking, and support innovation-driven education. The proposed center supports key national goals, especially Saudi Arabia’s Vision 2030. It aims to encourage economic growth through knowledge, strengthen local technology, and help people gain practical skills for today’s industries. By connecting universities and businesses, the center will open up new opportunities for research, entrepreneurship, and preparing people for the workforce. In conclusion, establishing a university-based 3D printing center is a forward-looking investment in the nation’s technological, educational, and economic sectors, redefining the role of universities as engines of innovation. This initiative prepares a generation to shape the future. At the same time, long-term challenges such as funding and client retention are addressed proactively.

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