

EXPLORING THE USE OF 3D PRINTING IN PHARMACY EDUCATION: A SCOPING REVIEW

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ABSTRACT

Three-dimensional (3D) printing technology has become an important innovation in the pharmaceutical field. In recent years, it has also gained attention in pharmacy education because it supports active learning, simulations, and hands-on experience. This scoping review explores how 3D printing is being used in pharmacy training, the benefits it provides, and the challenges that limit its adoption. Studies from 2015 to 2024 were reviewed from databases such as PubMed, Scopus, ScienceDirect, and Google Scholar. The results show that 3D printing can help students better understand drug design, formulation science, personalized medicine, compounding, and dosage form development. The technology also improves creativity and problem-solving skills. However, barriers such as lack of trained faculty, cost, regulatory uncertainty, and limited curriculum space remain major challenges. This review concludes that 3D printing has strong potential to transform pharmacy education and should be integrated gradually through structured learning models. [1–4]

KEYWORDS

3D printing; Additive manufacturing; Pharmacy education; Personalized medicine; Pharmaceutical training; Technology-enhanced learning.

1. INTRODUCTION

3D printing, also known as additive manufacturing, is a process that builds objects layer by layer from digital models. In the pharmaceutical field, it has been used for creating tablets, implants, drug-delivery systems, and patient-specific dosage forms. The first FDA-approved 3D-printed drug, Spritam®, marked a breakthrough in pharmaceutical manufacturing. Since then, research and professional interest in this technology has increased. [5]

Recent studies have shown that 3D printing can support pharmacy learning by making complex concepts easier to understand. Students can visualize and design dosage forms, observe drug release mechanisms, and practice compounding in a modern digital environment. This creates a bridge between theoretical knowledge and applied pharmaceutical science. [6][7]

Pharmacy is moving toward personalized medicine, and 3D printing allows learners to understand and prepare individualized therapies. For example, different doses, shapes, and release profiles can be created based on patient needs. This supports competence-based education, preparing students for future professional roles. [8][9]

Because of these advantages, many pharmacy schools have started introducing 3D printing in laboratory courses, electives, simulation-based learning, and research projects. However, there are still challenges such as cost, training requirements, and regulatory limitations. [10][11]

This review collects and summarizes published evidence to understand how 3D printing is currently being used in pharmacy education and what improvements are needed.

METHODOLOGY

This scoping review followed a simple structured approach to identify relevant published research. The goal was to collect evidence about how 3D printing is being used in pharmacy education and training. Articles published between 2014 and 2024 were included because this period represents the major growth of 3D printing in pharmacy. [12]

2.1 Search Strategy

Electronic searches were carried out using the following databases:

PubMed

Scopus

ScienceDirect

Google Scholar

The keywords used in different combinations included:

“3D printing”

“pharmacy education”

“additive manufacturing”

“pharmaceutical training”

“pharmacy curriculum”

“printed dosage forms for teaching”

Boolean operators such as AND, OR, and NOT were used to expand or narrow the search. [13]

2.2 Inclusion Criteria

Articles were included if they met the following conditions:

Discussed the use of 3D printing in pharmacy or healthcare education

Published in English

Available as full text

Peer-reviewed research, review articles, case studies, or academic reports

Studies describing 3D printing only for manufacturing purposes, with no educational context, were excluded. [14]

2.3 Screening Process

After removing duplicates, titles and abstracts were reviewed to determine relevance. Full texts were then analyzed. Out of approximately 112 retrieved articles, 39 met inclusion criteria and were selected for analysis. [15]

2.4 Data Extraction and Categorization

Key themes from each article were recorded, such as:

Purpose of 3D printing use

Learning outcomes

Type of printing technology

Student or instructor feedback

Challenges and limitations

These themes were grouped into major categories to summarize results in a simple format. [16]

2.5 Limitations of Method

This review only included English-language publications and may have missed relevant global research. Grey literature, unpublished student theses, and conference presentations were also not included. This may limit generalizability. [17]

RESULTS AND DISCUSSION

The reviewed studies showed that 3D printing is increasingly being adopted in pharmacy education, although its level of use varies from introductory demonstrations to full laboratory-based training. The findings from the selected articles were grouped into four main themes: teaching dosage form design, improving student engagement, supporting research skills, and barriers to implementation. [18]

3.1 Use of 3D Printing to Teach Dosage Form Design

Many studies reported that 3D printing helps students understand drug formulation and design because it allows them to create dosage forms in different shapes, sizes, and drug release patterns. Pharmacy students could design models of tablets, capsules, pediatric doses, and controlled-release forms. This hands-on learning helps bridge theoretical pharmaceutical science with practical application. [19][20] Studies also showed that students found it easier to understand concepts such as dissolution profiles and polymer selection when using 3D printing. [21]

3.2 Enhancement of Student Engagement and Learning Motivation

Articles also highlighted that students showed greater interest and motivation when 3D printing activities were added to lessons. Interactive learning experiences make educational activities more memorable. Students enjoyed designing and testing personalized drug dosage forms and felt more involved in the learning process. This approach supports student-centered learning and improves problem-solving and creativity. [22][23]

3.3 Support for Research and Innovation Skills

Some universities used 3D printing to encourage research projects in formulation science and personalized medicine. Students could test different materials (such as PLA, PVA, or pharmaceutical-grade polymers) and printing methods to evaluate drug release characteristics. This experience allows students to develop scientific thinking and prepares them for careers in pharmaceutical development, clinical compounding, or manufacturing. [24][25]

3.4 Challenges and Barriers to Implementation

Despite the benefits, several challenges were reported. The first challenge is the cost of printers, maintenance, and digital design software. Some institutions lack trained faculty to teach these tools. Additionally, regulatory uncertainty and lack of clear educational guidelines make integration difficult. Instructors also noted that developing training modules takes time and requires curriculum adjustments. [26][27]

3.5 Future Opportunities and Recommendations

Many publications suggested that 3D printing will likely become an important part of pharmacy education in the future, especially as personalized medicine becomes more common. Experts recommend integrating 3D printing gradually—starting with demonstrations, elective courses, or simulation labs and eventually expanding to core curriculum. Collaboration with engineering departments or industry partners can help overcome cost and training barriers. [28][29][30]

4. CONCLUSION

This scoping review demonstrates that the integration of 3D printing into pharmacy education has grown substantially over the last decade and continues to evolve with advancements in pharmaceutical technology [34,35]. Evidence from published studies indicates that 3D printing enhances learning by providing hands-on experience in drug formulation, dosage customization, and innovative delivery systems, making pharmaceutical concepts more tangible and practical for students [36,37].

Students exposed to 3D printing reported improved understanding of personalized medicine, increased confidence with compounding principles, and stronger engagement in laboratory-based learning environments [38]. Additionally, incorporating 3D printing into pharmacy curricula promotes critical thinking, creativity, and research competency, supporting the shift toward precision medicine and digital pharmaceutical manufacturing [39].

Despite these benefits, challenges remain. Limited access to equipment, insufficient staff training, and the lack of standardized educational frameworks remain barriers to widespread adoption across institutions [40]. Addressing these constraints through strategic investment, faculty development programs, and policy support may accelerate implementation and harmonization of 3D printing in pharmacy education.

Overall, the findings suggest that 3D printing holds significant potential as an educational tool in pharmacy, supporting future pharmacists in developing skills relevant to emerging roles in digital health and personalized therapeutics [41]. Continued research, interdisciplinary collaboration, and curriculum modernization will be essential to fully realize its academic and clinical value.

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