Investigating the Underlying Reasons for the Adoption of 3D Printed Models into Medical Education

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction:

Medical education has been highly debated since the early 1900s. The core of this debate is whether trained doctors should have a detailed, scientific knowledge of a biological understanding at the expense of a different type of knowledge based on humanistic characteristics. (Quintero, 2014). Humanistic education is a system that aims to promote the development of personalities, realize social values, and promote practical activities (Chen et. al., 2023). Research and discussion has shown that implementing a humanistic approach in medical education not only enhances medical students' communication skills and empathy, but also improves their professional ethics (Chen et. al., 2023).

In the last twenty years, changes in demographics, scientific achievements, and federal policies have had a major impact on healthcare (AAMC, n.d.). These changes will persist as society's needs continue to evolve, and consequently medical education will change as well. In order to introduce improvements to healthcare systems, medical professionals must acquire a comprehensive set of skills which range from the biological and cultural aspects of medicine to leadership and communication skills (Chen et. al., 2023). For this reason, the methods for medical education are highly researched and should continue to be investigated (Mourad et. al., 2016).

Medical practice has and will continue to rapidly evolve in response to technological advancements and changing patient needs (J Public Health Res., 2013). This progression of medical technology necessitates advanced teaching methods to equip medical students for the complexities of modern healthcare systems (Dacre & Fox, 2000). Traditional medical education methods, such as lectures and textbooks, struggle to meet evolving demands of medicine. Although some of these traditional teaching methods are foundational, they lack the interactive and dynamic elements essential to thrive in today's healthcare environment (Trans Am Clin Climatol Assoc., 2011). Relying solely on these methods is associated with the risk of producing medical professionals that are not prepared for the growth of modern medicine (Buja, 2019). To bridge the gap between education and medical practice, most medical schools have integrated novel interactive methods, such as 3D printing and modeling, into their curriculum. Despite this, studies on the effectiveness of 3D models in medical education have not demonstrated statistically significant improvements compared to conventional methods (Heliyon, 2023).

This paper argues through the Social Construction of Technology and Technology Acceptance Model that the underlying reason for medical schools' adoption of 3D printing technology into their curriculum is because of students' preferences and their interactions with other stakeholders in medical education. First, this paper will provide an overview of 3D printing as a teaching tool in medical education, with an emphasis on the reasons behind its recent widespread adoption into medical school curriculum. The literature review will cover the importance of interactive learning for doctor performance, the adoption of 3D models, economic challenges associated with 3D printing, and the statistical efficacy of 3D models as teaching tools. The literature review will also provide an overview of the sociotechnical frameworks, Social Construction of Technology and Technology Acceptance Model, that I intend to use. I will then analyze the effect of different social groups on the implementation of 3D printed models by looking at advertisements created by 3D printing companies, opinions from students on 3D models, and educators' and medical school board members' education policy documents. This will help me determine whether some social group is more influential in driving the adoption of 3D printed models into medical school curriculum. Through my analysis, I show that there is a relationship between 3D printing companies, students, and educational policymakers and find the reasons behind widespread implementation of 3D printed models in medical schools. I then conclude that while students' preferences and feedback play a significant role in changing educational strategies, 3D printing companies' marketing strategies and educational policymakers' decisions also contribute to the widespread implementation of 3D printed models in medical schools.

Literature Review:

Current medical education methods do prioritize interactive, or hands-on, learning, acknowledging the importance of practicing skills to improve performance. The Chair of Medical Education at the TCU School of Medicine stated that “a lot of physicians were trained in a model where they sat in classrooms from 8 a.m. to 5 p.m. … but there is a more efficient way to learn … you have to be able to practice a skill to get better” (Collier, 2019). He emphasizes that a more efficient way to learn involves practicing skills to improve performance, which will produce better doctors. He also stated that “so much of what we do in medicine, [is] not just about the knowing, it’s about applying the skill” (Collier, 2019). This further emphasizes the importance of interactive learning in medical education, as it will directly impact the way students perform as physicians. It is clear that some form of education where students can apply their knowledge is crucial to their success as doctors. Furthermore, evidence states that traditional subject-based and lecture-based curriculum has failed to accomplish the desired outcome of producing physicians for the current century. Content reformers are in favor of repealing major parts of traditional curriculum to make room for lessons that are aimed at improving students’ skills in modern clinical reasoning and decision making (Buja, 2019). Evidently, interactive learning has proven to be necessary in current medical education.

Because medical education needs to prioritize interactive learning, there has been a recent widespread adoption of 3D models into methods for medical education. As discussed, many studies highlight the need for interactive learning in modern education. Although traditional medical education methods were primarily lecture-based, medical professionals have understood the need for interactive learning for centuries (Dacre & Fox, 2000). Even as early as the 14th century, medical teaching mandated dissections for students (Ghosh, 2015). Since then, cadavers, virtual 3D models, and physical 3D models have been implemented in various ways to teach medical students (Anat, 2021). More specifically, 3D printed and computerized 3D models have been most recently adopted to provide enhanced visualization and enable personalized clinical simulations to students (Ardila et al., 2023). 3D printing is a novel technology that has shown great potential in surgical education and training in the form of physical models (Ye et. al., 2020).

With the widespread use of 3D models in medical curriculum, there are cost and resource challenges associated with their implementation. 3D models, including the installation of 3D printers and their materials, are more expensive and resource-intensive than traditional dissection tools (Brumpt et al., 2023). Despite these cost challenges, educational institutions are increasingly pushing for the shift toward 3D models in medical education. In addition, 3D models that are actually useful in medical education need to be detailed; limitations in adopting these detailed models include a significant trade-off between cost and fidelity (Yuen, 2020). For this reason, 3D models that are cost-effective might overlook the fidelity or accuracy of the model.

Furthermore, studies show no statistically significant improvements in learning outcomes for 3D models compared to conventional methods. One source shows that many studies conducted regarding the efficacy of 3D models in medical education have not shown evidence of statistically significant improvements in learning compared to conventional methods (Ardila et al., 2023). Another source also states that there haven't been statistically significant differences in learning outcomes between 3D models and conventional interactive methods like dissections (Azer & Azer, 2016). Moreover, the research that states that 3D models are "effective" in learning is typically measured with a short term memory quiz and might not actually be effective in practice for the long term (Azer & Azer, 2016). As discussed, practice is the most important in preparing students best for clinical examination and giving students a deep understanding of clinical subjects. Because of these drawbacks, it is important to question the true reasons for the implementation of 3D models, especially because they are costly.

I intend to investigate the underlying reasons for the increasing adoption of 3D models for medical education over more conventional methods. I use the Social Construction of Technology (SCOT) to identify the relevant social groups that facilitate the transition from conventional methods to 3D models in medical education. SCOT argues that technology is shaped by social processes and human choices, and that this is an interactive process among relevant social groups (Pinch & Bijker, 1984). Relevant social groups are defined as all groups of people that are involved in or affected by a technological development (Pinch & Bijker, 1984). In the context of my research, I have identified the relevant social groups to be educational policymakers, students, teachers, and 3D printing manufacturing companies. I plan to use the Technology Acceptance Model (TAM) to investigate how user motivation influences the adoption of new technologies in medical education. TAM proposes that a system's use is influenced by user motivation, which is directly influenced by the actual system's features and capabilities (Chuttur, 2009). In the scope of my research, this implies that the transition to 3D models is not entirely scientific, but also user motivated. I hope this will provide more insight into how the users, or students, along with the other relevant social groups, have driven the transition to 3D modeling.

Methods:

I conducted a literature review and discourse analysis to understand the different social groups' attitudes towards 3D models. I focused on collecting sources published within the last 20 years because the shift toward 3D models has been a recent transition. I used review articles that focused on student attitudes toward the implementation of 3D models. I also found educational policy documents from the medical accreditation board in order to draw a connection between the board's requirements and the rapid implementation of 3D models. Furthermore, I found advertisements from 3D printing companies to see whether the statements they present are backed by literature or are targeted to a specific social group. Through academic reviews, analysis of academic policy, and identification of marketing strategies, I hope to gain an understanding to identify the underlying reasons for the shift to 3D models in medical schools, with a focus on the relationships between social groups.

Analysis:

3D printing companies advertise their products as more advantageous and user-friendly than conventional methods. When searching a database for the top 3D printing companies for education, the companies "Formlabs," "StrataSys," and "FlashForge" all commonly appear. As stated in an article about medical 3D printing, these companies have transformed the desktop 3D printing industry with printers widely used in laboratories, industries, healthcare facilities, and research institutions (Patel et. al., 2023). The online presence of these companies shows that they are highly influential within medical education. The company StrataSys states that animals only approximate a human clinical experience, and that they're also expensive and require a controlled environment. Cadavers have limitations for this same reason, and while anatomically accurate, they don't retain live-tissue characteristics. Finally, StrataSys states that none of these options can fully and consistently represent a particular concept or disease (StrataSys, n.d.). As discussed previously, studies have shown that there are no statistically significant differences between dissections/cadavers and 3D models, so StrataSys is presenting inaccurate information in their advertisements for 3D models. Another company, Formlabs, stated in a paper that "[Surgeons'] knowledge has traditionally been conferred through preclinical studies in medical school, 2D imaging, human cadaver studies, and long hours in the hospital during residency. Adding 3D printed models to these existing tools has numerous benefits for medical students and residents, particularly those in surgical subspecialties. 3D printed models can expose trainees to a wider range of rare and complex patient anatomies" (Formlabs, 2017). Formlabs is stating that 3D printed models contribute to medical education by exposing students to a wider range of rare and patient anatomies, but this can be done more cost-effectively through dissections and other methods according to previous research. Lastly, in an advertisement for their "Educational Bundle" value pack, FlashForge states "Flashforge USA is committed for providing educational solutions to students, STEM/STEAM teams, and teachers across the nation with easy to operate 3D printers and 3D printing products" (FlashForge, n.d.). Many companies, in addition to this one, advertise their 3D printers as "user-friendly" and "easy to operate," which could lead to students and teachers preferring this method for modeling over other digital tools. In line with the TAM framework, users might be more motivated to use and adopt this technology if, through advertisements, it is perceived as easy to use and effective.

In addition to 3D printers being marketed as easy to use, students are more satisfied with their learning through 3D models. A review of studies states that students favored the use of 3D anatomy models and found them to be “more satisfactory” when compared to traditional teaching (Azer & Azer, 2016). Another literature review’s results indicated that students were more “satisfied” with their learning when taught with 3D printing techniques than students taught with conventional techniques (Ye et. al., 2020). Furthermore, the students taught with 3D printing had more confidence in test-taking and completed tests much faster than the other group (Ardila et. al., 2023). Although previous evidence shows that 3D printed models are not significantly effective in learning, these reviews show that students considerably prefer learning with 3D printed models. This could be because 3D models give students more confidence in their education as well as provide a method that might be easier to use than a cadaver or digital tool. According to the TAM framework, the users, which are students in this context, drive the adoption of a technology. These users might be more motivated to adopt 3D models because they prefer it to other methods for personal confidence, test performance.

Even if learning isn’t improved, students’ opinions matter because medical schools are required to implement student feedback and preferences in their courses and learning strategies in order to stay officially recognized. Most medical schools are required to be accredited, which means that that institution maintains a certain level of educational standards and quality (U.S. Department of Education, n.d.). The United States (U.S.) Department of Education recognizes the Liaison Committee on Medical Education (LCME) as the authority for accreditation of medical education programs in the U.S. (Cureus, 2023). According to LCME, medical schools must use the Independent Student Analysis (ISA) for full accreditation (LCME, n.d.). This is a component of the accreditation process that allows students and faculty to discuss the school's strengths and weaknesses and catalyze changes where reform is needed (UNC School of Education, n.d.). The ISA includes a section that assesses medical school responsiveness to student feedback on courses (LCME, n.d.). Because medical school responsiveness is taken into account, medical institutions must consider student's course feedback when designing their curriculum in order to stay accredited. This puts pressure on medical schools to adopt technologies that students think may be valuable, when in reality they have no proof in improving learning long-term. This is evident in the implementation of 3D models. Students give feedback based on the knowledge and beliefs gained through their learning. Evidence states, "feedback interacts with learners' knowledge and beliefs about themselves and about learning. They use feedback to change both their cognitive and behavioural learning strategies…" (Spooner et. al., 2023) Because learners prefer 3D printed models in their course feedback, medical educators will implement those strategies, even though they are not significantly more effective. The relevant social groups from SCOT all interact with 3D models in different ways, but they all shape each other's opinions of the technology. Preferences of students, who are influenced by the marketing messages of 3D printing companies, impact the degree of integration of 3D printing technology into medical school curriculum.

Some might argue that 3D printing might be adopted because it is a more sustainable alternative to traditional methods of interactive learning, like dissections, but this is not the case. Evidence suggests that "[animal] use and disposal, and the associated use of chemicals and supplies, contribute to pollution as well as adverse impacts on biodiversity and public health" (Groff et. al., 2014). Raising and farming animals for dissection has many environmental implications. The novel alternative to interactive teaching includes 3D models, rather than dissections and cadaveric studies. However, additive manufacturing, a 3D printing technique, has numerous environmental impacts as well. The primary issues include energy consumption, product life cycle, waste materials, water footprint, global warming potential, and air pollution (Khosravani & Reinicke, 2020). Furthermore, another source states that the extraneous plastic shapes and supports that 3D printing uses makes it very wasteful (Hoang, 2018). It appears that both dissection and 3D printed models have negative impacts on the environment, so adopting an interactive method of teaching that is more sustainable cannot be the reason for 3D models' increasing adoption into medical curriculum.

Conclusion:

It is evident that the true reasons for medical schools' adoption of 3D printing technology in their curriculum is influenced by user and other relevant social group preference. Through a discourse analysis of the relevant social groups, I found that 3D printing companies influence student preference, which puts pressure on medical schools to adapt their curriculum to what the students want, in order to satisfy their accreditation requirements. While this doesn't mean that 3D printing doesn't have a place in medical education, it instead implies that accepted standards of teaching may not be the best approach in all cases. For all educational practices, this argument encourages institutions and teachers to reflect on whether the curriculum they establish is the best way to teach students. Moreover, medical schools could potentially revise their curriculum to ensure that there is more transparency in the teaching methods they employ so students can understand why they are being taught the way they are.

The analysis with many of the different contributors to this novel field unveiled the adoption of a teaching technique used to educate future doctors. It might seem odd to consider things like the effect of 3D printing companies' effects on medical school curriculum. However, medical students' education is incredibly important, so it is important to view their education holistically in order to consider all factors that affect it. The SCOT framework allowed me to identify and analyze the relevant social groups in this method of education in order to take this holistic approach. In the future, other teaching methods could be analyzed through this framework in order to better understand whether views and preferences of other social groups are driving the use of those as well.

Limitations of my current argument stem from the fact that I didn't have the opportunity to do an ethnographic study observing students that interact with the technology. This could potentially identify additional reasons for student preference to 3D printing technology over conventional methods. Future work should address this limitation by observing how medical students interact with 3D printing technology and interviewing them about their preferences. Additional future research could look at whether this pattern is evident in teaching methods beyond just 3D printing in medical school education. Also, research could identify the degree to which other methods might be adopted into general education, and if that is influenced by a different relevant social group. By showing all the various relevant social groups and reasons that 3D printing is adopted into medical school curriculums, despite proof showing its lack of efficacy as a teaching method, I hope to spark further discussion towards bettering the education of our medical students to produce better doctors.

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