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Enhancing Gross Anatomy Courses in Occupational Therapy with 3D Applications: An Assessment of Effectiveness

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Abstract

Traditional teaching methods, such as two-dimensional PowerPoint presentations, are prevalent in anatomy education but must provide an in-depth perception of anatomical structures. This article discusses integrating 3D anatomy application in an Occupational Therapy course as an advanced technique for anatomical learning. The "Complete 3D Anatomy" app was employed to facilitate the teaching of anatomy structures. Students from 2 different cohorts, 93 from 2022 and 96 from 2023 test scores, were considered in this endeavor. The 2022 group used the 3-D app on their own time, compared to the 2023 group, who were required to use it in class for every lecture by the instructor. Results showed improvement in their test score from 71% (2022) to 87% (2023), with the integration of the 3-D as a class activity. Based on these results, it is concluded that the 3D anatomy app is an essential tool for comprehensive anatomical learning. For future courses, there is a plan to integrate further and assess the benefits of requiring students to employ a tablet or iPad equipped with 3D apps, along with a virtual dissection table to complement teaching and learning enterprises in the human cadaver laboratory.

Keywords: Anatomy application, Occupational Therapy, Anatomy teaching, Technology, App.

1. INTRODUCTION

Recent developments have prompted a reevaluation of traditional approaches to anatomy education (Brassett C. *et al.*, 2020). The complexities of teaching and comprehending the human body's structure necessitate innovative educational strategies (Hammond *et al.*, 2023). Anatomy teaching traditionally relied on textbooks, cadaver dissections, and lectures (Hammond *et al.*, P., 2003; Houser & Kondrashov, 2018). One of the significant limitations of using two-dimensional educational tools, such as those abovementioned, is the need for more conveyance of spatial depth and the arrangement of anatomical structures. This limitation often hampers the ability to manipulate anatomical models and accurately understand the spatial relationships among various structures, particularly smaller configurations like neuromuscular vessels (Berkowitz *et al.*, 2014). Many educational programs and institutions continue to employ the gold standard of cadaver dissection and prosection to enhance the anatomy learning process. Supplementing these techniques with various tools and strategies developed to facilitate the understanding of depth and the spatial relationships of deeper anatomical structures is the goal of improving the teaching and learning experience. These include anatomical models, virtual dissection tables, and virtual reality environments (Iwanaga J., 2020).

The integration of adjunct tools such as augmented reality (AR), three-dimensional applications, and virtual dissection tables offers numerous benefits in enhancing the educational experience (Uruthiralingam, U; Rea, PM, 2020; Bork, F, 2019). AR, in particular, has proven to be an effective supplementary tool for enhancing the understanding and instruction of anatomy. It has been shown to complement traditional learning modalities effectively, accommodating diverse educational backgrounds and specialties (Bork, F, 2019; Duncan-Vaidya, EA; Stevenson, EL, 2020).

Virtual dissection tables (VDTs) have facilitated manipulating and recognizing the interrelationships among anatomical structures, providing a comprehensive view of human anatomy (Rosario MG. *et al.*, 2019; Rosario MG 2022 & 2024; Brucoli M *et al.*, 2020). VTDs such as the Anatomage Table stand out for their life-size digital dissection table, which offers an unparalleled realistic experience of human anatomy. This tool is particularly beneficial in institutions with limited access to cadaveric material. It provides a virtual dissection experience, allowing for exploration and learning that closely mimics working with actual human cadavers (Rosario MG, 2022 & 2024). A study by Spitzer and Peck (2020) and another by Rosario MG (2022 & 2024) found that students using the Anatomage Table demonstrated higher engagement and better spatial understanding of anatomy than those learning through traditional methods.

However, the transition to online platforms has limited the usability of physical devices like AR goggles and virtual dissection tables. Consequently, three-dimensional virtual anatomy applications have emerged as a viable alternative, offering innovative and preferred methods for advancing anatomical knowledge in an online setting (Houser & Kondrashov, 2018; Chakraborty & Cooperstein, 2018; Rosario MG *et al.*, 2019; Rosario MG 2021a-b, 2022, 2024). These applications have demonstrated effectiveness in enhancing anatomical understanding, comparable to other adjunctive devices (Iwanaga J., 2020). Applications such as Visible Body can provide interactive, layer-by-layer views of the human body, allowing students to visualize the spatial relationships between structures effectively (Visible Body, 2020). One of the critical features of Visible Body is its user-friendly interface, which caters to both beginners and advanced learners, making it a versatile tool in education. According to a study by Patel and Moxham (2020), students who used 3D apps like Visible Body reported significantly improved understanding of anatomical positions and relationships compared to traditional learning methods.

Another 3-D app is Complete Anatomy, known for its high-resolution images and ability to manipulate anatomical models in three-dimensional space. This app provides detailed visualizations and includes clinical correlations, quizzes, and lecture materials integrated into its platform (3D4Medical, 2020). It supports a collaborative learning environment where instructors can customize content and share it with students, enhancing the educational experience (Rosario MG, 2021a). Research by Sugand *et al.*, (2016) and Rosario MG, 2021b highlights that Complete Anatomy has improved students' test scores, suggesting that interactive 3D models significantly contribute to the learning outcomes in medical education.

While traditional cadaver dissection remains irreplaceable, integrating three-dimensional applications into online anatomy courses can significantly supplement and enhance the learning experience. This approach is particularly advantageous when traditional, hands-on methods are impractical (Uruthiralingam, U; Rea, PM, 2020). Incorporating three-dimensional tools into anatomy courses' lecture and laboratory components can mitigate some 2-D teaching and learning challenges, fostering a tailored educational experience that enhances understanding and application of anatomical concepts.

In light of these observations, this discussion explores the benefits of incorporating three-dimensional anatomy applications into online anatomy courses, particularly for students in occupational therapy programs. This inquiry aims to highlight the potential of these advanced tools in overcoming the educational challenges posed by the shift to online learning environments.

2. METHODS

Participants

Ninety-three students enrolled in the 2022 and ninety-six in the 2023 Doctoral Program in Occupational Therapy cohorts participated in this study. These cohorts were distinguished by their use of a specific application. The 2022 group used the app independently, outside of class sessions, while the 2023 group utilized the same application during class for their summer semester gross anatomy course.

Equipment

The study employed the "Complete Anatomy" application on an Apple iPad Pro as a supplementary tool to enhance the understanding of various anatomical structures. The course format was face-to-face, using PowerPoint presentations for lecture delivery and cadaver prosections for laboratory sessions. The 3D anatomy application was integrated as an adjunct learning tool. Students accessed the application on their devices, which allowed them to engage with the 3D perspectives in real time during lectures, facilitating a more interactive learning experience.

Lecture and Laboratory Integration

The lectures and laboratory sessions were designed to highlight specific anatomical regions using PowerPoint presentations. These presentations were further augmented by demonstrating these structures in 3D through the application. The 3D component was then opened for discussion, prompted by questions from the anatomy instructor.

Assessments

The course included a midterm examination, written and practical component each contributing 100% towards the course assessment. The midterm examination covered anatomical structures of the upper back and upper extremities.

Data Analysis

The effectiveness of the 3D anatomy application was evaluated by comparing outcomes between app users, in class App Users Group, (ICAUG) and users outside of class App Users Group, (OCAUG).

At the beginning of the semester, all students purchased the app as part of their required course material. A one-way ANOVA was conducted to compare the performance of both groups. A p-value of 0.05 was established as significant in this analysis.

3. RESULTS

Appendix 1 shows the number of participants who contributed to this inquiry. To completely understand the effectiveness of the 3-D application, this study compares the average midterm score of ICAUG versus OCAUG. The ICAUG had a significant ($P \leq 0.001$) better average midterm score than the OCAUG.

4. DISCUSSION

This study evaluated the advantages of integrating a three-dimensional (3-D) anatomy application within classroom settings versus its utilization outside the classroom in an anatomy course tailored for occupational therapy students. Based on the findings from this investigation, embedding the 3-D anatomy perspective into lectures proved effective.

Students often need help to grasp the spatial relationships and depth perception among anatomical structures when relying solely on two-dimensional (2-D) educational resources, such as textbooks and anatomical atlases. Standard educational practices often employ PowerPoint presentations, which are inherently 2-D and may not adequately address these learning challenges. In response, this study explored the impact of incorporating a 3-D anatomical application into the curriculum to facilitate a more immediate and profound understanding of anatomical concepts.

The research identified a strong preference among students for the 3-D application during lectures and laboratory sessions, compared to traditional learning aids like textbooks, models, and atlases. Most students indicated that the application significantly enhanced their understanding of anatomy. These findings underscore the utility of incorporating the 3-D anatomy application into online and in-person educational settings. The outcomes align with other research highlighting the effectiveness of 3-D anatomy applications as supplements to traditional teaching methods (Ha, JE; Choi, DY, 2019). Given the positive impact observed, it is recommended that the 3-D anatomy application be integrated into relevant courses to enhance educational outcomes. This integration can be a significant educational adjunct, particularly in settings where understanding complex anatomical relationships is crucial.

The second outcome of this study pertained to differences in test scores among the groups. Most students performed satisfactorily, with an average passing score on the examination. This outcome indicates a measurable and significant benefit from using and interacting with the 3-D anatomy application, which enhanced their understanding of anatomy. Similar results have been noted in various studies examining the efficacy of adjunct tools for the comprehensive knowledge of anatomy. For instance, Peterson DC *et al.*, observed that students utilizing a 3-D perspective as part of their curriculum had a better grasp of complex anatomical regions and performed superiorly on assessments. Their research also suggested that the long-term retention of anatomical knowledge was improved through such tools, although interestingly, students only sometimes perceived these tools as beneficial.

Given these findings, the current study recommends incorporating dedicated sessions to master the skills required for effectively using tablets and devices equipped with the 3-D app, as Chakraborty TR Cooperstein DF (2018) suggested. We advocate for the mandatory inclusion of the 3-D application in anatomy courses, particularly in scenarios where cadaver dissection or prosection poses challenges. Furthermore, routine use of the 3-D app in classroom and laboratory settings is recommended to familiarize students with the technology and optimize its use for a deeper understanding of detailed human anatomy.

Despite the advantages of modern technological tools, a subset of students preferred traditional methods, favoring textbooks over applications. Specialized anatomy textbooks and atlases are valued for their role in reviewing and comprehending anatomical concepts. Many academic programs mandate specific textbooks and recommended readings, underscoring their entrenched status as essential educational resources. This study aims not to replace these established learning aids but to augment the existing array of educational tools with the 3-D app. By integrating this modern technology, we seek to enhance the traditional anatomy curriculum, offering students an additional resource that complements their learning experiences while accommodating different learning preferences and needs.

As previously noted, books and traditional screens are two-dimensional mediums that have inherent limitations in conveying depth perception and the precise location of anatomical structures. Rather than replacing books with applications, instructors should design activities that simultaneously utilize books and 3-D applications. Such integrated activities will enable students to effectively bridge the gap between theoretical concepts and practical applications in anatomy courses.

Upon integrating 3D technology into lectures and labs, there has been a noticeable increase in student enthusiasm and motivation for learning anatomy. This boost is attributed to the 3D perspective providing students with a comprehensive view in a succinct manner, a benefit similarly reported in previous studies

(Berkowitz *et al.,* 2014). However, rather than actively using the app to enhance their understanding of anatomy, students preferred more passive observation during demonstrations by the instructor. This observation aligns with findings by Peterson DC *et al.,* where students did not perceive a significant benefit from the addition of 3D technology.

Despite the limited number of students who recognized and appreciated the benefits of actively using and manipulating the 3D app during the course, taking these observations into account, we recommend mandating the incorporation of a 3D perspective into anatomy courses. Furthermore, it is proposed that this tool be embedded within lecture and lab sessions, creating assignments that encourage daily interaction with the app. Additionally, we suggest implementing activities where students take the lead (flipping the classroom) in demonstrating the anatomical topic or structure of the day using the 3D perspective. We are assured that these strategies will considerably enhance students' learning experiences and expedite their understanding of human anatomy.

As previously noted, cadaver dissection offers an unparalleled learning experience in anatomy education (Ghosh S.K., 2015). In light of this, anatomy supplements such as the application above serve as valuable alternatives. These tools assist in enhancing students' understanding, bridge the gap created by traditional lectures and two-dimensional images in online environments, and reduce the time required to connect theoretical concepts within lecture and laboratory settings (Krause *et al.,* 2015). The integration of such technology has been successfully tested across various educational scenarios, demonstrating significant benefits in student engagement and comprehension (Berkowitz S *et al.,* 2014; Brucoli M. *et al.,* 2018; Chakraborty & Cooperstein, 2018; Raney M, 2014). This study strongly recommends adopting 3D anatomy apps across all educational levels and disciplines in anatomy courses. Additionally, to counteract student passivity, it is proposed that dedicated class time be allocated for students to engage with the app through hands-on activities actively.

Beyond merely demonstrating the 3D anatomy application during lectures and labs, students must interact directly with the tool. Such interaction facilitates a deeper understanding of depth perception and the spatial orientation of anatomical structures, potentially accelerating the learning process. Combining 3D anatomy apps with traditional teaching methods such as lectures has enhanced the overall comprehension of human anatomy (Alsharif *et al.,* 2018; Lewis *et al.,* 2014; Berkowitz *et al.,* 2014).

Integrating these applications into anatomy education addresses challenges inherent in conventional teaching methods. Firstly, they provide an immersive learning experience unattainable with textbooks or static imagery. Secondly, these applications offer flexibility in learning, accommodating diverse learning paces and styles, which is essential in a varied educational environment. However, while these tools present significant advantages, they also demand suitable infrastructure, including hardware and software compatibility, and may necessitate a steep learning curve for both students and educators. Furthermore, the costs of these applications and the required technological equipment can pose financial challenges for some institutions.

In conclusion, three-dimensional (3-D) applications are instrumental in modernizing anatomy education. These tools offer dynamic, interactive, and intricately detailed visualizations of anatomical structures, significantly enhancing educational outcomes. As technological advancements progress, integrating these applications into anatomy education promises to be profound, potentially making them essential curriculum components.

The use of 3-D apps in educational settings not only caters to students' visual and interactive learning preferences but also facilitates a deeper understanding of complex anatomical details that are difficult to capture through traditional two-dimensional mediums. This capability to render detailed, manipulable 3-D models of human anatomy allows students to comprehensively explore and understand the spatial relationships and functional aspects of various body systems.

However, the adoption and integration of such advanced technologies must be approached with careful planning and consideration. It is crucial to ensure that these technological tools are accessible to all students and effectively integrated into the educational framework to maximize their potential benefits. This consideration includes addressing barriers such as the cost of technology, the need for compatible infrastructure, and providing adequate training for educators to utilize these tools efficiently.

Moreover, as we embrace these innovative tools, there is a compelling need for ongoing research and adaptive strategies in educational practices to fully leverage the advantages of digital advancements. This approach involves continuously evaluating the effectiveness of 3-D applications in enhancing learning outcomes, adapting teaching methods to incorporate new tools seamlessly, and ensuring that these technologies complement, rather than replace, traditional teaching methods.

These findings highlight the critical role of 3-D applications in transforming anatomy education and underscore the importance of strategic implementation and continuous improvement. By carefully integrating these tools into the educational landscape, we can significantly enhance how anatomy is taught and learned, preparing students more effectively for professional roles in healthcare and research, where a deep understanding of human anatomy is essential.

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APPENDIX 1

Appendix 1: Comparison among 3-D app OCAUG and ICAUG			
Characteristics	**OCAUG Participants n=93**	**ICAUG Participants n=96 WithApp**	**P value**
Grade	71.6 +/- 15.5	87.7 +/- 9.2	0.001
ICAUG-in-class app user OCAUG-outside of lecture app user			