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Low-Cost Holographic Pyramid for Teaching Heart Anatomy

Pirámide Holográfica de Bajo Costo para la Enseñanza de la Anatomía del Corazón

Wendell Nunes da Silva[1]; Emerson Roberto Santos[2]; Laura Cristina Nogueira Siqueira Knoch[2]; Fernando José Dias[3,4]; Diego Pulzatto Cury[1,5] & Ana Paula Cremasco Takano[1]

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SUMMARY: Human anatomy is fundamental to biological and health sciences curricula, traditionally taught through lectures combined with practical laboratory sessions. However, recent evidence suggests that active methodologies and interactive technologies may enhance student participation, satisfaction and the effectiveness of teaching and learning. We evaluated the usefulness of a low-cost pedagogical tool, the interactive holographic pyramid display. Designed for tablets and constructed from crystal acetate sheets, the holographic pyramid projects three-dimensional images of the heart's external and internal structures during systole and diastole. After attending a heart anatomy lecture, students participated in practical lab sessions that featured various learning stations, including one with the holographic pyramid. A questionnaire assessed their perceptions of the activity. Results indicated that 96 % of participants enjoyed the activity, and the use of the pyramid enhanced interest in anatomy. Additionally, more than 90 % of students agreed that the activity helped them assimilate the concepts discussed in the previous lecture class. The activity was well-received, suggesting the potential of low-cost holographic tools for complementing anatomy education. Future research should evaluate retention and performance outcomes using this technology-enhanced learning activity.

KEY WORDS: Holographic pyramids; Heart; Low-cost technology.

INTRODUCTION

Human anatomy is a fundamental discipline within biological and health sciences curricula. Traditionally, students have engaged in passive learning methods, primarily through expository lectures that introduce the basic concepts of human body structures. A significant challenge for educators is finding effective strategies to help students understand and retain anatomical content. To address this, educators continually seek to enhance their teaching methods, focusing students' attention on essential aspects and avoiding cognitive overload from lengthy lectures.

Recent evidence suggests that incorporating active methodologies and interactive strategies can encourage greater student participation and enhance class satisfaction. Integrating technology into teaching has become a strategy for deepening students' understanding of human anatomy. Notably, virtual reality, augmented reality, 3D printing (Adnan & Xiao, 2023), magic mirrors (Ma *et al*., 2016), and holograms (Miller, 2016; Rosen & Nesic, 2021) have gained prominence. Computer-assisted learning, especially with 3D visualization technology, has proven highly effective in enhancing factual and spatial knowledge (Losco *et al*., 2017).

Implementing these technologies may involve high costs. Therefore, it is essential to develop more accessible resources for a broader range of higher education and technical institutions to incorporate technology into anatomy teaching. As part of this effort, our study evaluates students' perceptions of a low-cost pedagogical approach using an interactive holographic pyramid display that we have developed. We believe that the holographic pyramid, which reflects three-dimensional images on its faces, can enhance students' understanding of specific organ's anatomy and their functions.

[1] Department of Anatomy, Institute of Biomedical Sciences, Universidade de São Paulo, São Paulo, Brazil.
[2] Lapa Grau Técnico, São Paulo, Brazil.
[3] Oral Biology Research Centre (CIBO-UFRO), Dental School-Facultad de Odontología, Universidad de La Frontera, Temuco, Chile.
[4] Department of Integral Adults Dentistry, Dental School-Facultad de Odontología, Universidad de La Frontera, Temuco, Chile.
[5] Department of Cell and the Developmental Biology, Institute of Biomedical Sciences, Universidade de São Paulo, São Paulo, Brazil.

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MATERIAL AND METHOD

The holographic pyramid can be constructed according to the screen size of each device that will display videos of human body structures, allowing adaptation for different types of devices. Therefore, cell phones, tablets, and monitors require different pyramid sizes (Fig. 1 A-C). We tested all sizes, but in this study, the pyramids were assembled for use on tablets available for undergraduate courses, according to the template shown in Figure 1. The materials used to construct the holographic pyramids were A3-size crystal acetate sheets, transparent tape, and suction cups, all easily found in stationery stores. The faces of the pyramids were joined with transparent tape along the internal and external edges. The apex of each pyramid was removed to accommodate a suction cup, securing the pyramid to the tablet's surface. Alternatively, the pyramids can be assembled using a mold that should be adjusted to fit the dimensions of the chosen device (Fig. 1D). Bright environments can hinder students' observation of details in the holograms. To reduce visibility loss due to high brightness, the pyramid bases were covered with black cardboard paper.

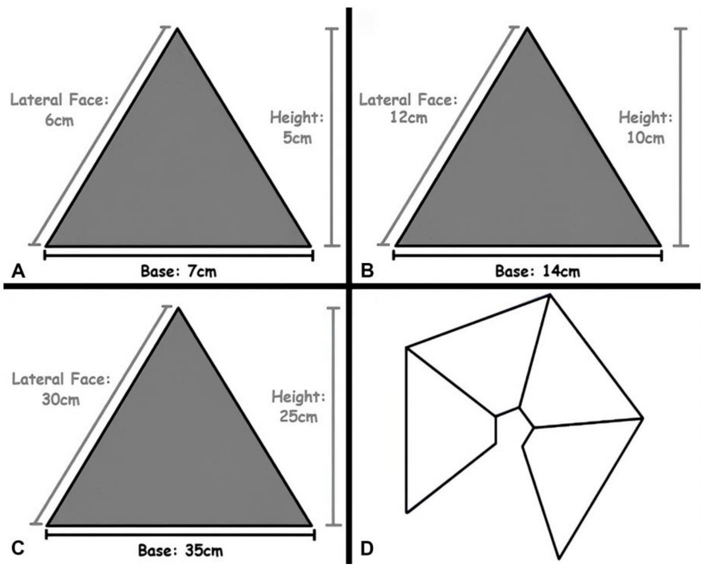

Fig. 1. Measurements of the pyramid faces for different device sizes: cell phones (A), tablets (B), televisions between 32 and 42 inches (C), and holographic pyramid template (D).

Each tablet and holographic pyramid displayed a distinct video: The first demonstrated the heart's external anatomy, the second showcased the internal anatomy of the left atrium and ventricle, and the third presented the internal anatomy of the right ventricle. All videos allowed students to observe anatomical structures during the cardiac muscle's systole and diastole movements. These videos were obtained from the Complete Anatomy application (3D4Medical Ltd), accessible to students and faculty through the University of Sao Paulo. WonderShare Filmora 11 (Wondershare Technology Co., Ltd) was used for compiling and editing the 5-minute videos, providing ample time for students to study cardiac cycle structures and functions. Following editing, the videos were published on YouTube. Figure 2 depicts the projected pyramid and one hologram.

The study was approved by the Research Ethics Committee of the Institute of Biomedical Sciences at the University of São Paulo, under approval number 76346023.0.0000.5467. All participants provided written informed consent. Nursing undergraduate students from the University of Sao Paulo enrolled in the course 'Integrated Basic Sciences for Nursing' were invited to participate. The students attended a two-hour lecture on heart anatomy. Afterwards, they were divided into small groups (5 students) for practical activities in the anatomy laboratory. Instructors directed students to various learning stations, including those with cadavers, prosection specimens, plastic heart models, and a workstation equipped with three tablets displaying holographic pyramids. A monitor at this workstation provided guidance on using the pyramid and explanations of the heart's external and internal anatomy, illustrating organ movements through holographic projections.

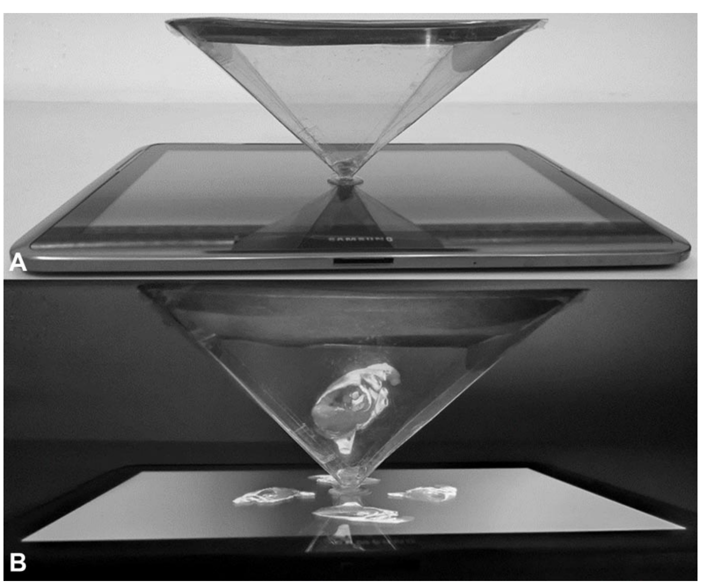

Fig. 2. Holographic pyramid used in the study. (A) Pyramid on the tablet, secured with a suction cup. (B) Image from the video highlighting the internal structures of the heart.

After completing the practical activities circuit, some volunteer students filled out a questionnaire containing eight Likert-scale questions, ranging from "strongly disagree" to "strongly agree." Additionally, an option for leaving open-ended comments was provided at the end of the questionnaire. The form was accessible via Google Forms, and printed copies were also available. Descriptive statistics were performed using GraphPad Prism 6 software. For open-ended responses, content analyses were conducted to group the responses into themes.

RESULTS

Twenty-five students participated in the study. Instructions for the activity using the holographic pyramids were simple and explained verbally. Consequently, 84 % fully agreed with the clarity of the instructions, while 8 % partially agreed. Regarding whether the activity helped assimilate class concepts, 72 % fully agreed, and 24 % partially agreed.

While students observed the holograms, the monitor encouraged reviewing concepts related to the heart's functional anatomy. When asked if they learned new information, 32 % responded neutrally, and 24 % disagreed. However, the activity motivated most students to learn and review class content (76 % fully agreed, 16 % partially agreed). Additionally, 68 % completely agreed, and 28 % partially agreed that the activity increased their interest in anatomy. Furthermore, 96 % claimed to have fun during the activity (80 % fully agreed, 16 % partially agreed), with only one student (4 %) finding it boring. The results are demonstrated in Figure 3.

Open-ended questions/comments about positive points, negative points, and suggestions were optional. All 25 students responded to the positive aspects, noting that the activity provided a means to review anatomy content, facilitated understanding of cardiac function, and offered an unconventional approach to learning. Fifteen students highlighted negative aspects, citing small tablet screens, overly bright rooms, and overcrowded groups. Twelve students suggested conducting the activity in darker rooms using monitors or televisions and increasing the number of practical sessions utilizing holographic pyramids.

DISCUSSION

Using three-dimensional heart models video projected onto a holographic pyramid provides students with an engaging way to review classroom content and encourages constructive discussions. This activity is especially effective for students who find videos and images more helpful than textbooks (Foutsitzi, 2018). Minimal resources are required for this activity, and it is best conducted in small groups at one or two learning stations to encourage participation and communication skills (Kitchen, 2012).

Previous studies recognize the didactic potential of holographic pyramids in teaching anatomy (Salih *et al*., 2017; Gafur *et al*., 2019), enhancing theoretical-practical interaction and student engagement (Fokides & Bampoukli, 2024). Holographic teaching has also been shown to enhance learning experiences compared to traditional methods (Paredes & Vázquez, 2020). An interesting study measured users' heart rates while observing their heart holographically (Thap *et al*., 2015). Yamanouchi *et al*. (2018), explored Leap Motion technology, enabling holographic objects to respond to hand gestures. Despite the high costs of sensors and equipment, these technology-enhanced learning methods can be adapted for higher education anatomy activities.

Our study focuses on developing a low-cost tool well received by students. The videos were made available on YouTube and edited using free tools. Students at our institution have access to the Complete Anatomy application, which was used to create the videos. This application offers detailed models that facilitate in-depth anatomical analysis (Lewis *et al*., 2014). However, the costs related to acquiring the application for institutions without it are high, and creating videos requires specific skills. To facilitate these

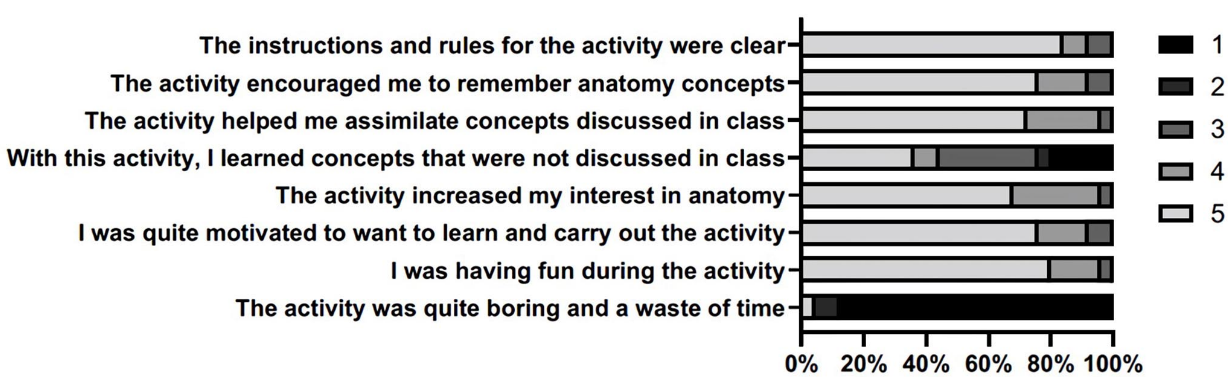

Fig. 3. Frequency distribution, in percentage, of responses to the different questions.

issues, free videos on YouTube can be used, but their quality may be inferior. Teachers should evaluate available materials for their pedagogical objectives and student profiles.

CONCLUSION

This initial work reports on the experience and student satisfaction with this low-cost tool. Holographic pyramids complement practical anatomy teaching. Although this study shows that accessible resources can incorporate technology into teaching anatomy, performance or content retention assessments were not conducted. Future work may provide evidence of the benefits of this practice with a more representative sample. The study evaluated students' perceptions of using a holographic pyramid for studying heart anatomy. The results indicate that this low-cost, interactive, technology-enhanced activity effectively increases motivation to learn anatomy and stimulates the review and assimilation of discussed concepts.

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RESUMEN: La anatomía humana es fundamental en los planes de estudio de las ciencias biológicas y de la salud, y tradicionalmente se imparte a través de conferencias combinadas con sesiones prácticas de laboratorio. Sin embargo, la evidencia reciente sugiere que las metodologías activas y las tecnologías interactivas pueden mejorar la participación, la satisfacción y la eficacia de la enseñanza y el aprendizaje de los estudiantes. Se evaluó la utilidad de una herramienta pedagógica de bajo costo: La pantalla piramidal holográfica interactiva. Diseñada para tabletas y construida a partir de láminas de acetato de cristal, la pirámide holográfica proyecta imágenes tridimensionales de las estructuras externas e internas del corazón durante la sístole y la diástole. Después de asistir a una conferencia de anatomía del corazón, los estudiantes participaron en sesiones prácticas de laboratorio que contaron con varias estaciones de aprendizaje, incluida una con la pirámide holográfica. Un cuestionario evaluó sus percepciones sobre la actividad. Los resultados indicaron que el 96 % de los participantes disfrutaron de la actividad, y el uso de la pirámide aumentó el interés por la anatomía. Además, más el 90 % de los estudiantes coincidieron en que la actividad les ayudó a asimilar los conceptos discutidos en la clase anterior. La actividad fue bien recibida, lo que sugiere el potencial de las herramientas holográficas de bajo costo para complementar la educación en anatomía. Las investigaciones futuras deben evaluar los resultados de retención y rendimiento utilizando esta actividad de aprendizaje mejorada por la tecnología.

PALABRAS CLAVE: Pirámides holográficas; Corazón; Tecnología de bajo costo.

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Corresponding author:
Ana Paula Cremasco Takano
Department of Anatomy
Institute of Biomedical Sciences
University of Sao Paulo
Av. Prof. Lineu Prestes 2415
Butantã, 05508000
São Paulo – SP
BRAZIL

E-mail: anatakano@usp.br