Holographic Applications in STEM Pedagogy and Training

Lawrence O. Flowers, PhD

Associate Professor of Biology, Department of Biological and Physical Sciences, Saint Augustine's University
Corresponding Author Email: *lflowers[at]st-aug.edu*

Abstract: ***Three - dimensional (3D) holographic technology, like virtual, augmented, and mixed reality technology, is an emerging technology designed to improve learning outcomes in science, technology, engineering, and math (STEM) disciplines. Holograms provide unique opportunities to enhance students' understanding of intractable concepts and processes using engaging visualization methods. Portable 3D holographic fans allow for the improved visualization of molecules, structures, pathways, and other STEM - related content that have the potential to elevate information acquisition in novel ways that extend beyond 2 - D presentations and textbook figures. While the potentiality of this innovative technology is exciting, adopting 3D holographic materials in the STEM pedagogical and research environment requires producing literary evidence to justify usage in specific contexts and sufficient guidance on safety protocols. A review of 3D hologram technology revealed an inadequate amount of efficacy research. Quantitative and qualitative research studies involving STEM majors, faculty, and researchers constitute the engine that will drive the utilization of 3D hologram visualizations in STEM undergraduate, graduate, and professional school classrooms and laboratories. The current article reviews relevant research findings and discusses the potential impacts of 3D hologram technology in teaching, research, distance learning, and medical contexts.***

Keywords: pedagogy; holograms; biology education; laboratory; distance learning

1. Introduction

A hologram or pseudo - hologram is a prominent three - dimensional image produced from a beam of coherent electromagnetic radiation (e. g., an LED - based device). In recent years, holographic technology has become more affordable, allowing it to be considered as a meaningful tool to increase intellectual and professional pursuits in academic and research environments. Some major 3D hologram projectors include the GIWOX 3D Hologram Fan, the Missyou 3D Hologram Projector, and the Wanther 3D Hologram Fan. By its very nature, 3D hologram technology is highly visual and may better support the teaching and learning goals of students who identify as visual learners according to standardized measurements. The next section of this article explores how 3D hologram technology educates and trains students and the reported benefits of the novel technology.

Using 3D hologram technology in conjunction with other active learning approaches may be more effective in academic settings than in isolation. For example, employing 3D holographic projectors combined with a student - centered active learning environment for undergraduate programs (SCALE - UP) teaching interventions could promote student engagement and satisfaction goals [1, 2]. Moreover, besides simply displaying content, some institutions have explored using holographic tutors and teachers to teach matriculants [3]. Such technology could also significantly improve distance learning frameworks and enhance student and professor interactions during online courses [4].

A study performed on elementary students showed that students who learned content using pseudo - holograms had more positive academic outcomes than those who learned similar content using traditional computer - generated 3 - D models. These studies would benefit higher education and medical education settings to garner support for this emerging innovative technology [5, 6]. This technology is poised to have clear benefits in biology, chemistry, geology, anatomy, engineering, geometry, biochemistry, astronomy, materials science, and immunology. Additional studies are needed to demonstrate student perceptions, engagement, and attitudes regarding hologram technology. Future studies that show differences in knowledge gains and GPA differences because of exposure to hologram technology will expand the field and improve STEM education.

2. Hologram Technology in STEM

While the number of research studies purporting the positive effects of 3D hologram technology in pedagogical and research settings is staggeringly low compared to other technological advances, some studies have addressed the impact of hologram utilization in pedagogy and examined the practical application of the technology in research and practical applications such as medicine. In one such study, researchers investigated student perceptions after exposure to 3D hologram rendering devices in an undergraduate organic chemistry course. Data from a virtual quantitative survey indicates that college students have favorable views when learning organic chemistry using holographic displays [7]. Evaluation of various article databases revealed a need for more research studies examining student attitudes toward 3D hologram technology in chemistry courses. Application and improvement to quantitative surveys such as the Digital Hologram Attitude Scale (DHAS) and Digital Hologram Reflection Form (DHRF) will assist researchers and pedagogical practitioners as we seek to understand how 3D hologram technology can improve student success in a variety of dimensions [8].

Further, incorporating reliable methods to teach and understand STEM students' visual literacy skills may determine the success of 3D hologram teaching interventions [9, 10]. Several studies have already been conducted to assess faculty perceptions of holographic methods in the classroom and show that, on average, faculty believe this technology can have profound impacts if appropriately employed [11]. There have also been calls in education to assist faculty by providing innovative technology training on campus. Too often, STEM faculty have trepidation in incorporating new educational technology into their courses. Sufficient training in usage, knowledge gain assessment, and technique evaluation studies would mitigate that apprehension and produce substantial gains in faculty confidence.3D hologram technology is suitable for many pedagogical activities in small or large classes in the STEM curriculum. The display of three - dimensional images in the educational environment can provide unprecedented views of STEM - related concepts and processes capable of enhancing learning beyond textbooks and laboratory manuals alone.

A significant student barrier to conceptual understanding is the need for concrete visual models of historically difficult academic material; 3D holograms can mitigate this barrier. The use of physical models can be cost - prohibitive over time, while subsequent improvements in hologram software will predicate the ability to produce virtually an unlimited number of educationally valuable images and virtual models that can span the STEM landscape for use in lectures, laboratories, class demonstrations, and faculty - mentored research training experiences. Reconstructing experimental models during research investigations can lead to the acceptance or rejection of hypotheses and even lead to the development of new or alternative hypotheses. Much like the benefits of the microscope, 3D holograms can drastically improve the visualization of virtually any type of phenomena. Three - dimensional hologram technology has been proposed in clinical applications to ascertain better the size and complexity of lung, liver, and colon lesions. Improving the visual examination of lesions is believed to expedite treatment selection [12]. Hologram technology has also been applied to enhance hepatectomy surgery for liver cancer patients. For example, using holograms during surgical procedures supports increased collaboration among surgeons by improving the spatial understanding of precise tumor locations and preoperative surgical planning [13, 14]. Moreover, hologram technology improves diagnosis and surgical planning of double outlet right ventricle (DORV) surgical procedures [15]. When applied to medical applications, holograms provide better resolution of critical tissues and organs, decreasing diagnostic and medical treatment planning and facilitating expedited medical engagement.

3. Conclusion

Another necessary element to cultivate 3D hologram usage is improving the software and applications designed to operate the technology. Current software for many devices is complicated and needs to be more user - friendly. Moreover, software that facilitates the ability to create and use custom images and produce holographic presentations is required for widespread adoption. Undergraduate and graduate school projects could involve student - guided coding to improve 3D hologram software and applications germane to individual STEM disciplines. Thus, interdisciplinary collaborations will advance the field of holographic technology and augment its applicability. While this article discussed a small portion of the potential uses of 3D hologram technology, there are many ways this technology can be used at universities, laboratories, healthcare facilities, and industry. For example, college/university recruitment presentations using 3D hologram technology may increase student enrollment longitudinally. Given the nature of the oscillating fans and potential safety hazards, special instruction is necessary to mitigate risks associated with bodily injury when using this visually stunning technology. Always read the instructions carefully and device information when implementing the technology. Ensure device usage occurs in a location with ample space to limit injury risk.

Consult the manufacturers of the portable hologram fans for helpful information regarding optimal usage. Additionally, future research studies are necessary to fully understand how this technology can transform STEM courses, learning centers, research, and specific applied disciplines such as medicine, crop science, and pharmacology.

Quality studies examining the effects of this technology to increase workforce preparation and professional development activities would be exciting and potentially chart a new pathway to preparing students for employment. Research probing the ramifications of 3D holographic applications in minority - serving institutions such as historically black colleges and universities (HBCUs), tribal colleges and universities (TCUs), and Hispanic - serving institutions (HSIs) is virtually nonexistent. Members of these racial groups have been reported to be highly visual learners and could benefit from using this technology in educational and training settings. Many minority - serving institutions have limited operating budgets; however, many portable hologram fans are becoming more cost - effective.

Academic departments should consider 3D hologram training on their campuses to assist STEM faculty in its use. The development of certificate programs in the use of 3D hologram technology, as well as other pedagogical technology, may improve faculty competency and student outcomes. In conclusion, data from this article shows that overall educational studies are severely lacking regarding the effectiveness of hologram technology in STEM. However, several existing studies suggest positive student and faculty perceptions regarding 3D hologram applications. STEM students generally believe this technology can support their academic growth and understanding of core content.

Acknowledgements
This work was supported by grants from the National Science Foundation (EES - 2205612, EES - 2232563, EES - 2306512).

References

[1] Felege C, Ralph S. Evaluating the efficacy of a student - centered active learning environment for undergraduate programs (SCALE - UP) classroom for major and non - major biology students. Journal of Biological Education.2019; 53: 98 - 109.

[2] Chittum J, McConnell K, Sible J. SCALE (ing) - UP teaching: A case study of student motivation in an undergraduate course. Journal on Excellence in College Teaching.2017; 28: 119 - 157.

[3] Ali A, Ramlie M. Examining the user experience of learning with a hologram tutor in the form of a 3D cartoon character. Education and Information Technologies.2021; 26: 6123 - 6141.

[4] Kalansooriya P, Marasinghe A, Bandara, K. Assessing the applicability of 3D holographic technology as an enhanced technology for distance learning. IAFOR Journal of Education.2015; 1: 43 - 57.

[5] Fokides E, Kilintari E. Examining the educational value of 3D LED fan displays. Results of a project. Education and Information Technologies.2023; 28: 11101 - 11116.

[6] Moro C, Phelps C, Jones D, Stromberga Z. Using holograms to enhance learning in health sciences and medicine. Medical Science Educator.2020; 30: 1351 - 1352.

[7] Olić - Ninković S, Adamov J. University students' opinions on the use of 3d holograms in learning organic chemistry. In V. Lamanauskas (Ed.), Science and technology education: New developments and innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023) (pp.151 - 161).2023; Scientia Socialis Press.

[8] Turk H, Seckin - Kapucu M. Innovative technology applications in science education: Digital holography. Journal of Education in Science, Environment and Health.2021; 7: 156 - 170.

[9] Erro A, Menendez - Pida S, Cruzado R, Suz A. A framework for visual literacy competences in engineering education. Journal of Visual Literacy.2022; 41: 132 - 152.

[10] Chai C. Enhancing visual literacy of students through photo elicitation. Journal of Visual Literacy.2019; 38: 120 - 129.

[11] Jafari E. Explanation of the views and opinions regarding the education strategies for using 3D hologram technology as an educational media. Educational Media International.2023; 60: 67 - 91.

[12] Ryu S, Lee S, Yoon K, Baek J, Kim K. Design of a compact hologram system capable of 3D lesion diagnosis in clinic. Surgical Innovation.2023; 30: 762 - 765.

[13] Saito Y, Sugimoto M, Imura S, Morine Y, Ikemoto T, Iwahashi S et al. Intraoperative 3D hologram support with mixed reality techniques in liver surgery. Annals of Surgery.2020; 271: e4 - e7.

[14] Checcucci E, Amparore D, Pecoraro A, Peretti D, Aimar R, Cillis S.3D mixed reality holograms for preoperative surgical planning of nephron - sparing surgery: Evaluation of surgeons' perception. Minerva Urology and Nephrology.2021; 73: 367 - 375.

[15] Ye W, Zhang X, Li T, Luo C, Yang L. Mixed - reality hologram for diagnosis and surgical planning of double outlet of the right ventricle: A pilot study. Clinical Radiology.2021; 76: e1 - e237.