International Journal of Innovative Research and Scientific Studies, 8(1) 2025, pages: 1239-1244

IJIRSS International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Enhancing science learning: The impact of holograms in chemistry and biology classes in Jordan

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Abstract

The technological and communications revolution has contributed to the development and innovation of many modern technologies that help humanity, the most important of which is hologram technology, a new tool that holds promise for improving education and enhancing the learning experience in schools. Our study examines the use of holograms in chemistry and biology courses in Jordan's public high schools. Data collected from 156 teachers in the spring semester of 2024 reveal that holograms effectively facilitate information delivery to students and increase understanding of course content. The study also highlights the opportunities available to successfully incorporate holograms into the educational system in Jordan, such as the need for funds and grants to support the availability of this technology for students. In addition, the study mentions challenges being experienced, such as the high cost of hologram technology and the need for proper training for teachers. Overall, hologram technology offers a promising educational tool if financial concerns are resolved to facilitate this technology in Jordanian high schools.

Keywords: Biology, Hologram, IOT, Learning, Opportunities.

DOI: 10.53894/ijirss.v8i1.4574
Funding: This study received no specific financial support.
History: Received: 13 December 2024/**Revised:** 14 January 2025/**Accepted:** 24 January 2025/**Published:** 7 February 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

Information and communication technology (ICT) has brought major changes in the way people communicate around the world, making interactions faster and easier. It has also led to the emergence of the "Internet of Things," which allows devices to communicate with each other and automate many tasks. In addition, cloud computing has made it easier to store data and use software over the Internet. While e-commerce and data analysis have changed the way businesses operate, hologram technology has added unique experiences in entertainment, education, medicine, and design, opening new doors to learning within schools. Holograms can simplify complicated scientific concepts by creating three-dimensional (3D) visuals that students can interact with, making complex subjects more engaging and easier to understand. For example, in a biology class, students explore the detailed structure of a cell in a 3D visualization, or in a history class, where they can study historical events through holographic simulations. This technology can be adapted to different learning styles, making lessons more dynamic and memorable. However, the successful use of holograms requires prior planning, such as adequate training for teachers and the facilitation of the necessary equipment and technical infrastructure. Overall, holograms have the potential to advance education by providing interactive and visually rich learning experiences.

The term "hologram" is derived from the Greek words "holos," meaning whole, and "gram," meaning message. Holography was invented by physicist Dennis Gabor in 1947 and later refined to its modern form by Emmett Leith and Juris Upatnieks in the 1960s [1]. The technology continued to be developed in optical engineering after World War II [2].

Over the years, hologram technology has undergone significant improvements in both hardware and software, leading to enhanced realism and a wider range of applications. Figure 1 shows the most important events during the development of hologram technology [3].

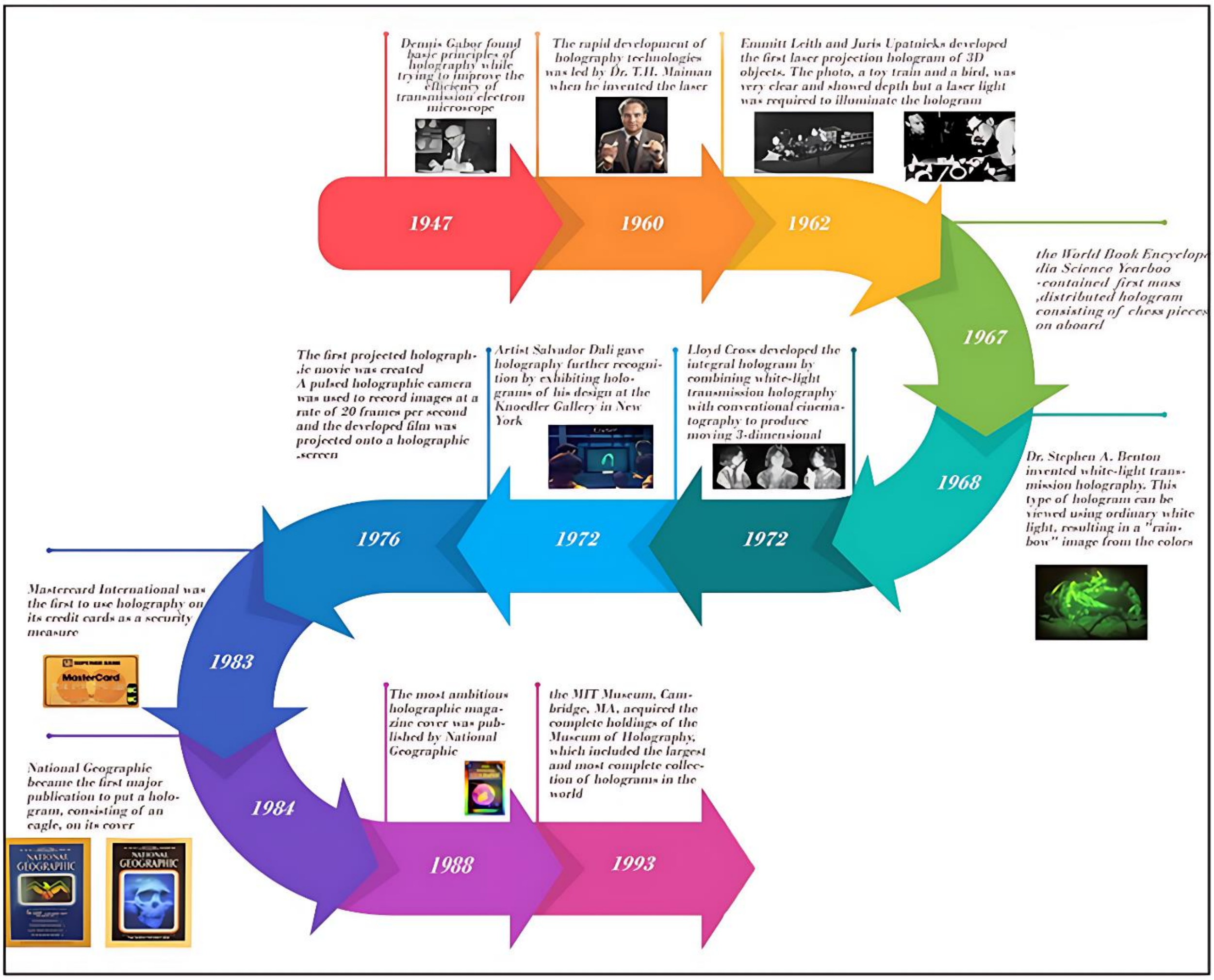

Figure 1.
Hologram technology timeline.

The rapid development of hologram technology has had a positive impact on different disciplines [4, 5], ranging from artistic and entertainment purposes to scientific and industrial uses, such as data storage, microscopy, and security features on credit cards and banknotes. This technology offers an exciting educational approach by explaining scientific concepts using three-dimensional visualizations, leading to engaging students with dynamic content [6].

Hologram technology has many benefits in education, i.e., it simplifies information and facilitates its acquisition by students and contributes to the embodiment of data and information that are difficult for students to comprehend. The hologram has a set of characteristics, such as allowing the viewer to see the object from all directions and providing clarity of the object's details. It enables the viewer to observe the movement of the object or shape and its transformation from one form to another. Additionally, it can display several holographic images on one board without interference between the displayed objects and store a huge amount of information, which reduces the risk of data loss, as the data from the missing part can be retrieved from the other parts. The hologram also possesses interactive kinetic and auditory characteristics, as each holographic cell works to analyze the light in the direction of the viewer's eye. Therefore, whenever the viewer moves and adjusts their viewing angles, they receive a new set of holographic images. Khan in Khan, et al. [7] indicated a set of hologram characteristics in the educational process as follows:

1. Stereoscopy: The hologram allows the component to be seen in three dimensions at a 360° angle.

2. Imagination: Providing the hologram with depth and a sense of producing reality in a distinctive and attractive manner for the learner.
3. Comprehensiveness: The hologram enables learners to see objects from all dimensions and move around them in four directions.
4. Concealment: The photographed object can be seen, and its changes and transformations into another form appear before the learner as if it is suspended in space.
5. Quality: The fragmentation of the hologram does not prevent the entire image from being seen because each part of the hologram film contains complete information.
6. Interactivity: The hologram has decorative and kinetic properties that provide the viewer with a sense of reality when moving to see a new angle of the photographed object.

This manuscript is organized as follows: Section 2 contains the research objectives, the literature review is in Section 3, followed by the research method in Section 4, while the discussion and results are in Section 5. The conclusion and future work are in Section 6.

2. Research Objectives

We collected teachers' opinions regarding the use of hologram technology in teaching chemistry and biology courses in public high schools in Jordan. We focused on discovering the strengths, opportunities, and challenges of using hologram technology in these subjects within public high schools.

3. Literature Review

The use of hologram technology in school and university courses has been studied previously in different disciplines. Al Mukhallaf [8] has used holograms in the English as a Foreign Language (EFL) course among middle school students [7]. The study involved 84 students divided into experimental and control groups. Findings have shown significant improvements in communication skills, as well as positive feedback from students towards learning using hologram technology compared to those taught through traditional methods. Data were collected using a comprehensive EFL communication skills test and an attitude scale, both of which demonstrated reliability and validity. The study highlighted the necessity of integrating innovative technologies like holograms into educational practices to overcome the challenges of poor communication skills and negative attitudes towards EFL. Overall, research suggested that the use of these strategies can better align with the digital age, promoting interactive learning for students.

Moreover, Flowers [9] utilized holography in science, technology, engineering, and mathematics (STEM) education and training [9]. The study highlights that a deeper understanding of complex concepts using 3D holography was achieved through improved visualization, significantly enhancing information comprehension. The study also outlines the current gaps in the literature regarding the impact of holographic technology on student learning in higher education and medical training. It shows that while some studies revealed positive feedback from students regarding the use of holograms in courses like organic chemistry, comprehensive research is still lacking. The author emphasizes the necessity of interdisciplinary collaborations to improve software usability, availability, and the appropriate training programs for faculty. Overall, 3D holograms can enhance pedagogical practices in STEM, improving student engagement and educational outcomes. Other researchers have illustrated the strengths and weaknesses of holographic technology as a teaching tool in general, evaluating its potential impact on higher education and proposing suggestions to educational institutions for adjustments to incorporate hologram technology effectively [10].

4. Research Method

In our study, we contacted 156 public school teachers in Amman (the capital of Jordan) during the spring semester of 2024 to fill out a survey after the use of hologram technology in teaching chemistry and biology courses. Survey questions were divided into two sections: the first focused on participant demographics, including gender, qualifications, and experience. The second section aimed to evaluate the strengths, opportunities, and challenges of using hologram technology in chemistry and biology courses. Teachers of these subjects often experience difficulties explaining certain concepts using traditional methods. A 5-point Likert scale was utilized, with a score of 5 indicating "Strongly Agree" and a score of 1 indicating "Strongly Disagree," while "Agree," "Neutral," and "Disagree" were assigned scores of 4, 3, and 2, respectively. The questions were adapted from previous studies [11, 12] and were modified to suit our study context. Data were analyzed using SPSS (SPSS Statistics for Windows, v21.0. IBM Corp., USA).

5. Results and Discussion

The demographic details of the participants are shown in Table 1. The majority of participants (~93.6%) had a bachelor's degree. In addition, most participants (~96.8%) had at least 3 years of teaching experience.

Table 1.
Participants demographics.

Variables	Characteristics	Frequency	Percent%
Gender	Female	81	51.9
	Male	75	48.1
Qualification	BSC	146	93.6
	MSC	10	6.4
Experience	1-2 years	5	3.2
	3-5	73	46.8
	>5	78	50.0

Cronbach's alpha coefficient assesses internal validity and item consistency, demonstrating reliability [13-15]. As shown in Table 2, the use of hologram technology revealed excellent reliability, with a coefficient of 0.895 for strengths, 0.854 for opportunities, and 0.819 for challenges.

Regarding our first research question, “What are the strengths of integrating hologram technology in chemistry and biology courses in public high schools?", most teachers agreed that using holograms helps explain some concepts in their courses with a mean of 4.0577 points on the Likert scale. We conducted an in-depth analysis, calculating the mean of the items designed for this purpose, as presented in Table 2. This is coherent with a previous study that suggested that 3D hologram technology can be an innovative tool in education by assisting both teachers and students [16]. In addition, teachers evaluated the statement “using holograms in the course will improve academic achievement” with a mean of 3.9808 points. It was also indicated that visual holograms enhance understanding, assisting students in acquiring long-term memory of information; thus, leading to better academic performance with 3.9103 points. Responses to the survey (Table 2) also suggest the advantage of using holograms in large classes, where students tend to be more distracted, in addition to saving time and increasing student excitement (Table 2). These findings align with Matere, et al. [17], who found that students are more actively interacting when using hologram technology, connecting theoretical concepts with practical experience, and leading to better learning outcomes [17]. These results indicate that easier understanding of concepts positively impacts students' achievement and retention of information. Holograms can quickly and clearly illustrate complex concepts without lengthy explanations or physical demonstrations. They can reduce the time needed to deliver some ideas by providing 3D visualizations of complex concepts, making it easier for students to understand and visualize certain concepts. For example, the chemistry course includes multiple concepts such as organic molecules, their structures and bonds, their nomenclature, and properties [11]. Students spend a relatively long time understanding these concepts while hologram technology makes these topics easier to absorb by illustrating the 3D visualization of the geometric structure of molecules and bonds [18, 19], and laboratory work [20]. For biology courses, 3D hologram technology provides better understanding of the size and structure of organs such as the lungs, liver, and colon, and how these organs perform their functions. The ability to effectively teach a large group of students at the same time is important for time efficiency. Moreover, hologram technology offers an educational tool providing all students with the same quality of information. Dynamic and visually interesting tools like holograms can attract students' attention and make learning more entertaining.

Table 2.
Strengths, opportunities, and Challenges of integrating Hologram technology in chemistry and biology courses.

Constructs	Items	Cronbach's alpha	Mean	Rank
Strengths	Using holograms in the course will help to explain some concepts more clearly.	0.0.895	4.0577	1
	Using holograms in courses will improve academic achievement.		3.9808	2
	By using holograms in the course, the students have long-term memory.		3.9103	3
	Suitability for large classes		3.8590	4
	Saving time in teaching		3.7628	5
	Increasing student engagement and enjoyment.		3.6538	6
Opportunities	Grants from the government and institutions can assist in funding holograms.	0.854	3.6987	1
	New improvements in holograms can make teaching better.		3.6667	2
	More digital learning tools make it easier to use holograms in teaching.		3.5962	3
	More interest in new teaching methods can help us use holograms.		3.5385	4
	Working with technology companies can help bring holograms into our classrooms.		3.5321	5
	Holograms can enhance personalized learning for students.		3.4679	6
Challenges	High cost of technology	0.819	4.0641	1

Constructs	Items	Cronbach's alpha	Mean	Rank
	Educational policies		4.0321	2
	Training		3.8013	3
	Preparation of lecture using hologram		3.6923	4
	High speed internet		3.5577	5
	Electricity and its interruptions		3.5064	6

Regarding the second research question, “What are the opportunities of integrating hologram technology in chemistry and biology courses in public high schools?” responses are presented in Table 2. The majority of teachers agreed that the most important part is to gain funding from government and educational grants to pay for holograms, with a mean value of 3.6987 points. This shows the financial barriers against adopting hologram technology, as addressed previously [21]. This was followed by the need for continuous technical improvements in holograms, with a mean value of 3.6667 points, which can significantly enhance the functionality and affordability of the technology, making it more practical for classroom use. In addition, the availability of more digital tools and environments can facilitate the integration of holograms into existing educational tools. Increased interest in innovative teaching methods is also important, as it creates a supportive environment to adapt holograms and other new technologies. Collaboration with technical companies supports additional resources and expertise, though it is shown to be of lesser priority compared to funding and technological improvements, which was also shown previously [22, 23].

In response to the third research question, “What are the challenges of integrating hologram technology in chemistry and biology courses in public high schools?”, Table 2 shows that high cost was rated as the biggest challenge with a mean of 4.0641 points, similar to previous findings in the literature [2, 24]. Without adequate funding, the adoption and maintenance of hologram technology become unfeasible. Likewise, the limited updates and flexibility in educational policies were shown as another challenge with a mean of 4.0321. This was indicated in a study by Matsika and Zhou [25], who identified the lack of synchronization of educational policies as a challenge in adopting new and advanced technologies faced by teachers [25]. The lack of policy updates can delay and complicate the use of newer educational tools due to the lack of funding. As such, without addressing financial constraints, even well-designed policies cannot facilitate the use of holograms. If the financial aspect is managed, policy issues become crucial in ensuring that the technology can be effectively and legally used. Policies can be adapted or developed after the initial financial investment is secured. Proper training for both teachers and students is essential for the successful utilization of holograms. Without effective training, the potential benefits of holograms may not be realized. The time and effort required to prepare lectures using holograms are significant. This factor affects how readily teachers can incorporate this technology into their lectures. Moreover, internet speed issues are a crucial factor for the effective use of the technology but are less concerning than funding or proper training challenges. While important, power supply issues might be less common, and they are often addressed through standard infrastructure.

6. Conclusion and Future Work

As educational tools continue to grow, hologram technology presents a new innovative tool for teaching chemistry and biology courses. However, to fully implement their potential in different educational disciplines, it is crucial to acknowledge both their benefits and obstacles that may hinder their use. Holograms significantly enhance the learning experience, particularly from the teachers' perspective, offering innovative ways to engage students and clarify complex concepts. However, significant challenges are present that can obstruct the use of holograms in schools, especially in low-income countries, such as high costs, educational policies, and limited availability of advanced technology. Addressing these challenges is vital to ensure an improved and better learning experience for all students. The authors suggest a recommendation for future work, which is to collect public school students’ opinions in Jordan regarding the use of hologram technology in chemistry and biology courses to gain a more comprehensive view of the perception of holograms in these courses.

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