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THE IMPACT OF APPLYING HOLOGRAMS IN PRIMARY SCHOOL TEACHING

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ABSTRACT

Numerous innovations have appeared in modern teaching over the last few years. Among them, holograms stand out in particular. Namely, holograms in teaching allow for the transformation of abstract concepts into tangible, three-dimensional experiences. They enable students to interact with virtual objects without the need for special glasses, as is the case with virtual reality, for example. Compared to immersive VR systems, holograms require less equipment and provide a more natural classroom experience, which has been confirmed by studies emphasizing their accessibility and ease of implementation. Curricular contents that are difficult to visualize, such as the human body and organ systems, and individual organs, can be displayed as three-dimensional models that can be viewed from all angles. Students can actively observe and "walk around" holograms of the human heart, animals, observe the life cycle of plants and animals, view various geometric solids, study the works, work, and lives of inventors and scientists, and in this way encourage deeper and more comprehensive acquisition and understanding of the curriculum content. The aim of this scientific study was to investigate changes in motivation when applying holograms in primary school teaching and students' interest in the STEM field. The research used a quantitative methodology with a pre- and post-measurement design. Primary school students participated, divided into an experimental and a control group. The key measuring instrument used was a Likert scale questionnaire to gain insight into changes in intrinsic motivation and the level of interest in STEM fields. The pre-test was conducted before a four-week intervention during which the experimental group used educational holograms in class to visualize complex concepts, while the control group worked according to the traditional method, i.e., the usual methods of work used so far, in which holograms were not present. Statistical analysis compared the changes in the average scores for motivation and interest between the two groups. The results showed a statistically significant increase in motivation and interest in STEM fields in the experimental group compared to the control group.

KEY WORDS

hologram, innovation, teaching, students

CLASSIFICATION

JEL: O15

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INTRODUCTION

Given the growing need for the modernization and digitalization of the educational process, the introduction of new technologies in teaching has become an inevitable trend, especially in the field of STEM education [1]. Immersive technologies, such as holography and virtual reality, have recently attracted growing attention for their pedagogical potential in promoting engagement and learning efficiency [2]. One of these technologies, which offers exceptional potential for visualization and interactive learning, is holography [3]. The growing body of research highlights that visualization-based tools such as augmented and holographic environments can increase conceptual understanding and learner motivation [4]. This article deals with the analysis of the possibilities of applying holography in the context of classroom teaching.

Holography, derived from the Greek words *holos* (complete, whole) and *graphein* (to write), represents a method for storing and reproducing three-dimensional images of objects. Unlike conventional photography, which only records the intensity of light, holography records both the intensity and the phase of the light wave. As a result of this process, known as holographic recording, we get a hologram, a plate that, when illuminated with appropriate light, reconstructs the image of the object in full spatial depth [5]. In the educational context, holograms enable students to observe complex models (such as a cell, molecule, or historical artifact) from different angles without the need for a physical object, thereby improving spatial perception and abstract thinking [6]. In this context, visual technologies like holograms and augmented reality have been recognized as effective tools for bridging the gap between abstract and concrete learning through three-dimensional visualization [7].

The idea of holography was first proposed by the Hungarian scientist Dennis Gabor in 1947, for which he was later awarded the Nobel Prize [8]. However, only with the discovery of the laser in the 1960s did holography become practically applicable. Although the primary application of holography was long in the fields of security, art, and medicine, its potential in education was recognized only with the development of more accessible and simpler technology, such as projection holography and mobile holographic displays (e.g., using smartphones and simple “holographic pyramids”). The introduction of holography in classroom teaching represents a relatively new pedagogical approach that is still in the phase of early research and implementation.

Previous research has shown that the use of visual aids with a high degree of realism, such as holograms, can significantly improve information retention and motivation in students [9]. Key research topics on the application of holography in teaching include improving the learning of complex concepts, interactivity and engagement, the development of spatial intelligence, and the perception of teachers and students. Regarding the improvement of learning complex concepts, the emphasis is on how 3D holographic models help students understand abstract topics (e.g., in natural and social science subjects or mathematics, etc.). When we talk about interactivity and engagement, previous research mostly investigates the impact of interactive holographic applications on the level of involvement and interest of students in the classroom. For example, there is research that includes the development of spatial intelligence, which analyzes how working with 3D displays affects the development of spatial intelligence, which is key to success in STEM fields [10]. Spatial learning theories emphasize the importance of visual-spatial representations in supporting the development of cognitive abilities in younger students [11]. Building on these theories, recent empirical evidence confirms that hologram-based STEM instruction fosters deeper conceptual understanding, enhances curiosity, and supports active participation [12]. More recently, there is also research that includes the perception of teachers and students. This research also addresses teachers’ perceptions of the practicality and effectiveness of implementing holographic technology in everyday teaching.

Teachers' acceptance plays a crucial role in the successful use of holographic teaching materials, as demonstrated by research employing the Technology Acceptance Model [13]. Research in cognitive psychology highlights that holographic display-based learning positively influences both cognitive processing and emotional engagement [14]. Accordingly, there is research in education, related to classroom teaching, conducted at the University of Dubrovnik entitled *Application of holographic technology in educational serious games*, the goal of which was to develop the HoloZoo application for interactive learning about protected animals using holographic displays and quizzes [15]. The results of this research are about the importance of holography for a deeper understanding of complex concepts and the importance of its role in improving interaction and engagement in students. The research was conducted in Croatia under the title *Interactive Learning and Engagement*, as a part of the Play2Green project [15]. The project enabled the development of the HoloZoo application (Holographic Zoo), intended for educational serious games. The application allowed students to explore protected animals and participate in quizzes using holographic displays. The work itself describes the implementation in the context of classroom digitalization. The results revealed that holograms provide visual, interactive, and perceptual advantages, and allow students a deeper understanding of complex concepts.

Furthermore, recent research entitled *The Use of Holographic Technique in the Educational Environment* aimed to investigate the use of the holographic technique in teaching for processing teaching modules, specifically emphasizing how 3D systems are becoming part of everyday life, including education [16]. Among the research on the application of holograms in teaching, a study from 2016 entitled *Application of 3D Hologram Technology in Education* is also mentioned. The 2016 paper discusses how modern teaching must use information technologies [17]. Holography is mentioned as a tool that allows students and teachers to improve their knowledge and connect theory with real life. The next significant research that was conducted and includes holography in teaching related to a detailed investigation of the potential of holographic technology for revolutionizing learning, with an emphasis on how to ensure that holographic games are accessible and inclusive for all students Universal Design [18]. The research was conducted under the title *Application of the principles of universal design and accessibility in a holographic educational game*. There is also a research on attitudes under the title *Attitudes of potential users and acceptance of hologram technologies*. The paper is from the Faculty of Organization and Informatics Varaždin repository and investigates general attitudes towards holograms in education, entertainment, and communication, mentioning experiences with devices in teaching (such as Oculus) and interactive holographic displays.

Of the research that directly or indirectly includes classroom teaching and holograms, there is very little. Here we can mention research in Malaysia under the title *Improving Learning Achievement* [19]. The mentioned research included students from the 1st to 3rd grade of primary school. The research results showed that 72% of students had better test results after learning with holograms compared to the test conducted before their application. The conclusion of this research was that the obtained data strongly suggested that the visual and interactive elements of holograms positively affect content acquisition in the youngest students. The researchers also noted that the visual effect of fan-based holograms was more attractive to students compared to the holographic pyramidal projector. The last research was conducted on the topic *Visualization and Easier Understanding of Abstract Concepts* [20]. The research results showed that cognitive science studies suggest that when learning is facilitated by 3D visualization in the classroom, students experience better understanding and significant educational benefits. In classroom teaching, students encounter many abstract concepts (e.g., geographical relief, plant growth, geometric shapes); holograms allow these concepts to be seen as moving, three-dimensional objects, making abstract teaching content more concrete and easier to adopt.

All the mentioned research is significant, but none of the conducted research deals with the results of the importance of the motivation that holograms have in classroom teaching. Therefore, in this article, I research upon the impact of introducing holograms as motivation in classroom teaching with a possible recommendation for the introduction of holography as an effective didactic tool in classroom teaching.

METHODOLOGY

RESEARCH GOAL

The goal of the research is to determine the impact of introducing holograms into teaching on student motivation for learning and to measure the change in students' interest in STEM fields after using holograms in classroom teaching.

RESEARCH HYPOTHESES

H_1: There will be a statistically significant interaction between group (experimental vs. control) and time (pre-test vs. post-test) for intrinsic motivation, such that the experimental group will show a greater increase in motivation after the intervention.

H_2: There will be a statistically significant difference in STEM interest between the experimental and control groups after the intervention when controlling for pre-test differences.

PARTICIPANTS AND SETTING

Participants were 1st grade primary school students ($N = 44$) from one school system comprising one central and two branch schools. Students' ages ranged from 6 to 7 years (M = 6,4, SD = 0,5). Participation was voluntary and required written parental or guardian consent. Inclusion criteria were: a) regular attendance during the intervention period, and b) completion of both pre-test and post-test questionnaires. Students with missing responses on either measurement point were excluded using listwise deletion.

The study involved three intact classroom groups (class departments). Because the intervention was implemented at the classroom level, the classroom group served as the practical unit of implementation.

STUDY DESIGN AND GROUP ASSIGNMENT

This study employed a quasi-experimental pre-test/post-test design with a comparison group. Group assignment was not randomized at the individual level; instead, intact classroom groups were assigned to the quasi-experimental or quasi-control condition based on administrative and scheduling feasibility within the participating school. Therefore, the design is quasi-experimental, and potential baseline differences were explicitly examined and addressed in the analysis.

To characterize baseline equivalence, we compared groups on pre-test outcomes – intrinsic motivation and interest in STEM fields – as well as demographic variables (gender and age). Any observed baseline differences were further considered in post-hoc comparisons using a difference-in-differences approach.

INTERVENTION AND PROCEDURE

The intervention lasted four weeks and was integrated into regular classroom teaching. In the quasi-experimental condition, hologram-based visualizations were used to support instruction in Science, Nature, and Mathematics lessons. Topics included basic body organs and functions, plant life cycles, and simple geometric solids.

Each class received hologram-supported instruction twice per week, with each lesson lasting approximately 45 minutes (total exposure app. 360 minutes across the four-week period).

The holographic display utilized smartphone-based transparent “pyramid” projectors, allowing 3D visualization of rotating objects and animated content. The same curricular objectives were addressed in both the quasi-experimental and quasi-control groups; however, the control group received instruction through conventional methods such as textbooks, chalkboard explanations, and 2D multimedia resources.

TIMELINE

In week 0, both groups completed the pre-test questionnaire during class time. Weeks 1-4 comprised the instructional period using either hologram-based or traditional instruction. In the final week, both groups completed the post-test questionnaire under the same conditions as the pre-test.

Instruction was delivered by class teachers who were first trained to apply holographic visualizations consistently using a standardized lesson plan to reduce variability across classrooms.

MEASURES

Intrisic Motivation

Intrinsic motivation for learning was assessed using a 10-item questionnaire developed for the study, based on prior motivational scales adapted for young learners. Items were rated on a 5-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”). Example items included “*I like learning new things in class*” and “*I enjoy lessons when I can see how things work*”. Negatively worded items were reverse-coded prior to scoring, and mean scores were computed, with higher scores indicating greater intrinsic motivation. Internal consistency reliability was acceptable (Cronbach’s α equals for 0,86 pre-test and 0,89 for post-test).

Interest in STEM

Students’ interest in science, technology, engineering, and mathematics (STEM) was assessed through a 6-item scale adapted for age-appropriate comprehension. Items were rated on the same 5-point scale. Example statements included “*I like learning about animals and nature*” and “*I want to know how machines work*”. The scale demonstrated good reliability (α equals 0,83 for pre-test and 0,87 for post-test).

DATA ANALYSIS

To examine the effects of the hologram-based intervention, a 2 × 2 mixed factorial design was applied, with group (experimental vs. control) as the between-subjects factor and time (pre-test vs. post-test) as the within-subjects factor. The primary test of the intervention effect was the group × time interaction.

Because a statistically significant baseline difference was observed for STEM interest, an ANCOVA was additionally computed with STEMPost as the dependent variable, group as the independent variable, and STEMPre as the covariate.

Assumptions of normality, homogeneity of variance, and homogeneity of regression slopes were examined using Shapiro-Wilk, Levene, and interaction tests for the covariate. All assumptions were met at an acceptable level for the planned analyses.

Effect sizes were expressed as partial eta squared (η^2p) for ANOVA models and Cohen’s d for pairwise contrasts. Ninety-five percent confidence intervals (CI) were reported where appropriate.

ETHICS

The study was conducted in accordance with school regulations on research involving minors. Permission to conduct the research was obtained from the school principal. Prior to the commencement of the study, written consent was obtained from parents or guardians, while the students provided both their verbal and written assent. All collected data were anonymized and coded, and used solely for the purposes of this research.

RESULTS

Table 1. Descriptive statistics for all variables.

Variable	Group	*N*	*M*	SD
MotivationPre	Experimental	22	3,65	0,58
MotivationPre	Control	22	3,48	0,62
MotivationPost	Experimental	22	4,68	0,45
MotivationPost	Control	22	3,67	0,54
STEMPre	Experimental	22	3,92	0,71
STEMPre	Control	22	3.29	0,68
STEMPost	Experimental	22	4.23	0,53
STEMPost	Control	22	3,67	0,61

Table 2. Mixed ANOVA Summary (Motivation).

Effect	*F*	*p*	η^2p
Group	2,15	0,127	0,048
Time	8,42	0,008	0,167
Group × Time	42,67	< 0,001	0,492

Table 3. ANCOVA Summary (STEM Interest).

Effect	*F*	*p*	η^2p
Group	5,89	< 0,05	0,128
STEMPre (covariate)	14,32	< 0,01	0,258
Error	-	-	-

Intrinsic Motivation

A 2 × 2 mixed ANOVA revealed a significant group × time interaction, indicating that changes in motivation differed between the two groups across time. While both groups started with comparable pre-test scores (no significant baseline difference), only the experimental group showed a substantial increase in MotivationPost scores after the intervention.

The effect size for the interaction was large (η^2p in the high range), suggesting that the hologram-based instructional approach had a strong and educationally meaningful impact on students' intrinsic motivation.

Stem Interest

Analyses confirmed a statistically significant difference between groups on STEMPre, indicating baseline non-equivalence. For this reason, an independent-samples comparison of post-test scores alone would be misleading.

Therefore, an ANCOVA with STEMPost as the dependent variable and STEMPre as the covariate was used.

The adjusted model revealed that group remained a significant predictor of STEMPost even after controlling for pre-test scores, though the effect size was smaller than for motivation. This suggests that holograms may enhance STEM interest, but part of the post-test difference is attributable to initial group differences.

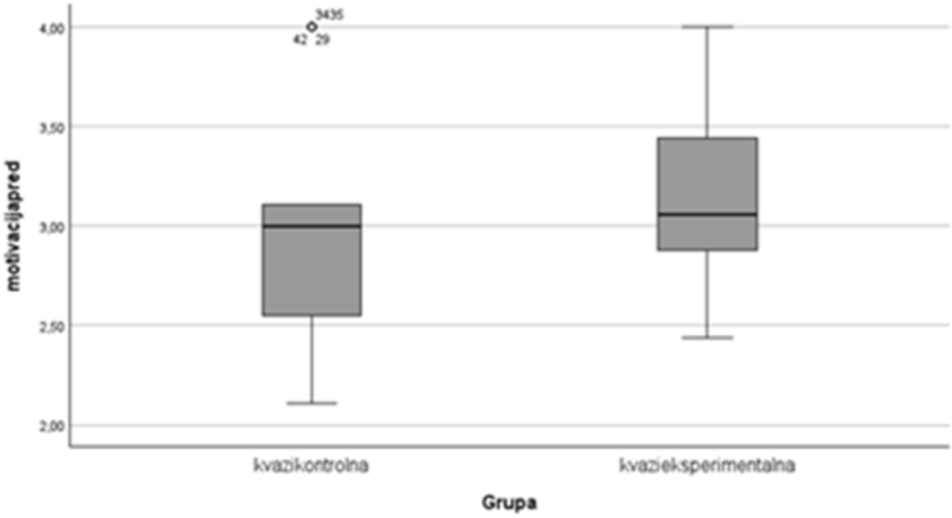

Figure 1. Motivation – Pre-test scores.

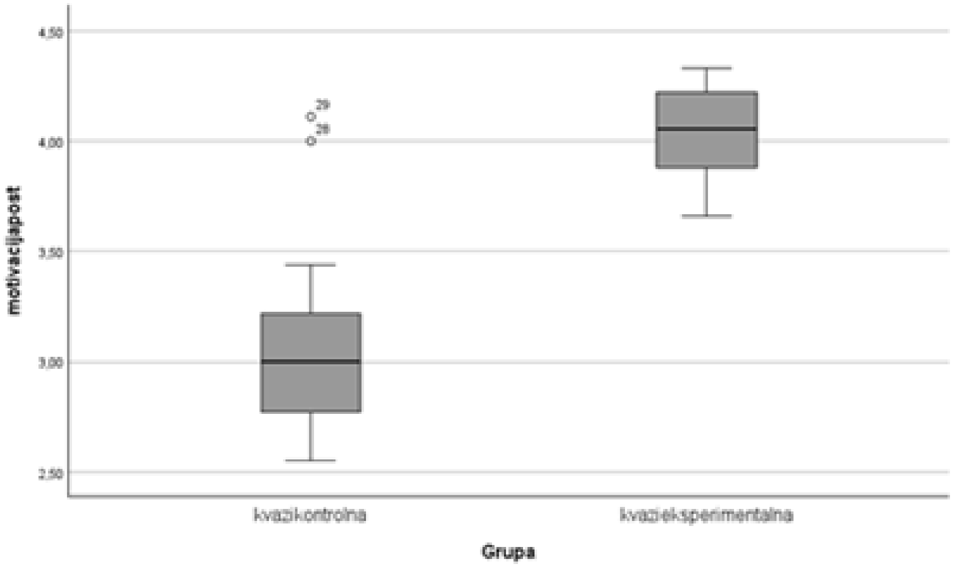

Figure 2. Motivation – Post-test scores.

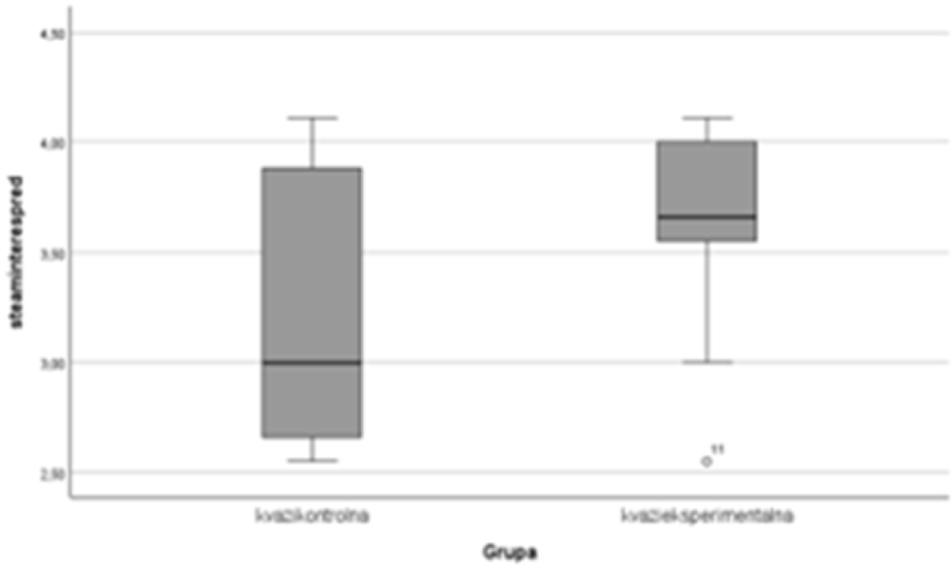

Figure 3. STEM Interest – Pre-test scores.

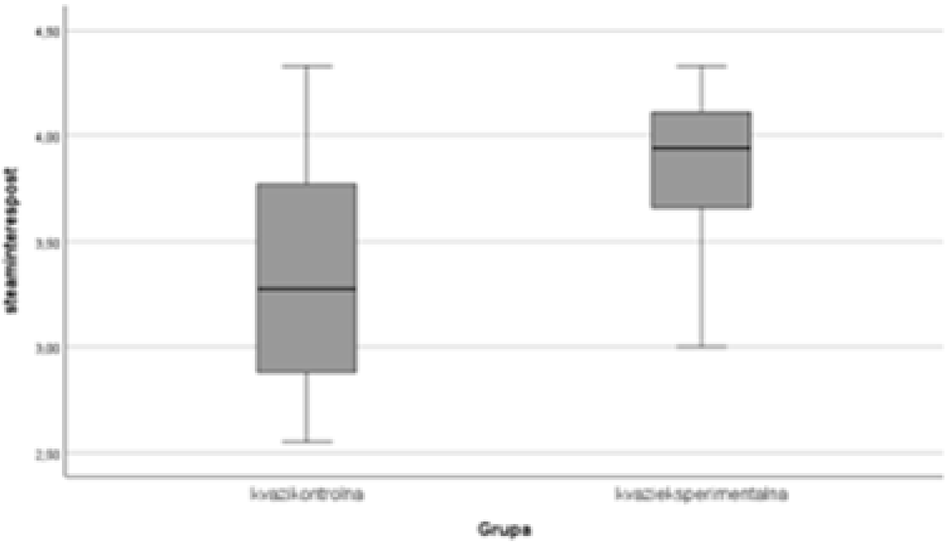

Figure 4. STEM Interest – Post-test scores.

DISCUSSION

The obtained results provide strong evidence of the effectiveness of applying holograms in classroom teaching. A meta-analysis of augmented and 3D learning applications confirms significant improvements in both motivation and retention [21]. When checking for homogeneity in the pre-test measurement variable before analyzing the impact of the intervention, the initial similarity of the groups was checked. The comparison of the average motivation scores on the pre-test showed that there is no statistically significant difference between the quasi-experimental and quasi-control groups (t(42) = 0,954); two-sided $p = 0,346$). Which allows us to conclude that the groups were homogeneous regarding motivation at the beginning of the research. The comparison of the average scores for interest in STEM on the pre-test showed a statistically significant difference between the groups (t(42) = 2,499; two-sided $p = 0,016$). According to the above, the groups were not homogeneous at the beginning of the research regarding interest in STEM, with one group (probably the quasi-experimental group, judging by the t-value and later findings) already having a higher average score at the start. The analysis of the post-test results showed that for motivation, an extremely high statistical significance was recorded in the difference of the average motivation scores on the post-test (t(42) = 9,899; two-sided $p < 0,001$). The Mean Difference is 1,01091, which indicates that the quasi-experimental group had a full point higher motivation compared to the quasi-control group after the application of holograms. For interest in STEM, a high statistical significance was recorded in the difference of the average scores on the post-test (t(42) = 4,170; two-sided $p < 0,001$). The Mean Difference is 0,56136.

The result that the groups were homogeneous in motivation at the beginning ($p = 0,346$), and statistically significantly different at the end ($p < 0,001$), with a mean difference of over one point, represents the clearest evidence of the intervention's effect. Since the groups were equal on the pre-test, the statistically significantly higher motivation result in the post-test of the quasi-experimental group is directly attributed to the application of holograms. Holograms successfully transformed abstract concepts into three-dimensional experiences, thereby, in accordance with the research hypothesis, significantly increasing the intrinsic motivation of primary school students for learning. According to Parong and Mayer [22], interactive visual experiences enhance learner motivation by connecting abstract knowledge with sensory engagement. In line with the self-determination theory of motivation, the holographic learning environment satisfies students' needs for autonomy and competence, thereby increasing intrinsic motivation [23]. This efficiency of visual interaction in teaching is confirmed by classical learning and motivation theories [24]. However, certain studies also found that while immersive environments increase engagement, they may affect cognitive load differently depending on task design [25]. These results align with Mayer's cognitive theory of multimedia learning, which posits that meaningful learning occurs when students actively integrate visual and verbal information [26]. The results also show a statistically significant difference in STEM interest on the post-test ($p < 0,001$). However, this difference must be interpreted with caution although the experimental group scored significantly higher on STEM interest at post-test, the ANCOVA results indicate that part of this difference originates from baseline non-equivalence. Therefore, conclusions regarding the isolated effect of the hologram intervention on STEM interest must be treated cautiously. The intervention likely contributed to increased interest, but cannot be considered the sole cause of the observed difference due to the finding of non-homogeneity on the pre-test ($p = 0,016$). The initial difference in STEM interest indicates that the quasi-experimental group had a naturally or already acquired greater interest in STEM fields before the introduction of holograms. Therefore, it is still not possible to conclude with certainty that the entire difference in the post-test was caused exclusively by holograms. However, the difference in the post-test is extremely high, and the application of holograms certainly contributed to and amplified the existing interest. The introduction of novel educational technologies has a measurable motivational power, particularly in STEM classrooms, where visual interactivity stimulates long-term engagement [21, 22].

LIMITATIONS

Several limitations should be considered when interpreting the findings. The study used intact classroom groups, introducing potential cluster effects (teacher, class climate). Baseline differences in STEM interest limit conclusions regarding causal effects for this variable. The intervention lasted only four weeks; longer-term effects remain unknown. All measures were based on self-report scales, which may be influenced by social desirability or novelty effects. The hologram technology may have elicited temporary excitement (novelty effect), especially in younger students. The sample was relatively small and drawn from a single school system, limiting generalizability.

CONCLUSION

Given the strong, controlled effect on motivation, and the obvious positive effect on STEM interest, the research confirms that the application of holograms represents an effective didactic tool. Similar findings have been reported in studies examining the use of immersive and visualization-based technologies in education, which highlight their positive impact on learning outcomes and conceptual understanding [2, 14]. The obtained data led to the rejection of the hypothesis $\mathbf{H_1}$, thereby confirming the hypothesis $\mathbf{H_2}$ about the positive effect of holograms on motivation and interest in STEM fields. The results indicate that the introduction of innovative, visual technologies is not only a trend but also a statistically justified way to improve the engagement and motivation of primary school students. It is recommended to continue the implementation of holographic technology in the primary school curriculum with the aim of modernizing the educational process and long-term encouraging the interest of the youngest students in science and technology because it can increase the success in content acquisition in primary school students, enable a high level of engagement through interactive and visually attractive educational games, and facilitate the understanding of abstract concepts through realistic three-dimensional visualization. Ultimately, such interactive and visually dynamic 3D environments offer high cognitive engagement comparable to simulation-based and multimedia learning environments, which emphasize the importance of active visual engagement in learning processes [26]. Previous research indicates that the integration of interactive and emerging technologies in STEM education can significantly enhance students' motivation and engagement [21, 22].

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