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Effect of Teaching Science through 3D Visualization on 8TH Graders' Achievement in Science

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ABSTRACT

This study explores the effect of teaching science through 3D visualization on 8th grader's achievement in science, focusing on their understanding of key scientific concepts such as the Human Nervous System, Variation, Heredity, Cell Division, Biotechnology, and Acids, Bases, and Salts. The objective is to explore how 3D visualization enhances students' understanding of these topics compared to conventional teaching methods. This quantitative study will follow a true experimental design, using a pre-test-post-tests control group design to compare student performance in both control and experimental groups. Permission was sought from the principal of elementary schools, and a school was selected conveniently based on the approval of the head administrators. In the selected schools, grade eight students were divided into two groups through matching pairs based on the pre-test results. A student was randomly assigned to one control group and an experiment group with 15 students in each group. The instruments were used, a science achievement test developed from a general science book grade eight, for pre-test and post-test. The Interventions were implemented. Students will be taught through 3D visualization videos on the projector. After the completion of the invention, a post-test was conducted. SPSS version 20.0 was used to analyze data; it was found that students who used 3D visualization had significant results compared to conventional teaching methods. Therefore, science teachers may use this teaching method to improve science achievement.

Keywords: *3D visualization, science teaching, experimental design, student achievement, science motivation, science anxiety*

INTRODUCTION

The rapid growth of technology has introduced new techniques in education, particularly in science learning (Malik et al., 2017). Among these, 3D visualization has emerged as an effective tool for improving traditional instructional methods by creating an interactive, engaging environment. This study will explore the effect of teaching science through 3D visualization on 8th grader's achievement in science, a crucial period where fundamental scientific ideas are constructed. In grade eight students often have difficulties understanding abstract science concepts. Students are introduced to basic concepts in biology, physics, and chemistry at this stage, which form the foundation for higher-level studies. Without detailed demonstrations, these science concepts can appear confusing. This may cause students to become anxious or lose interest in science. Many students in this period lose interest in science, which is frequently associated with the subject's perceived difficulty (Ainsworth, 2016). However, the use of 3D visualization technologies may assist in filling this gap by making complicated ideas more interesting.

The 3D visualization helps students acquire and retain scientific ideas and increases their interest and engagement with science classes. According to prior studies, 3D visualization may significantly improve student motivation and enhance cognitive learning results (Lecuyer, 2017).

Science is often perceived as more in-depth and observational than other subjects (Miller, 1991). According to Johnstone (1991) suggested that the challenges in learning science are due to its complexity and often invisible nature. For example, some scientific concepts are difficult to understand because they can't be easily observed directly. Elementary students struggle to understand complex concepts (Sun et al., 2010).

Traditional science teaching methods, which often emphasize rote memorization and lecture-based instruction, can make the subject particularly difficult for many learners. These approaches may fail to engage students effectively in different learning styles, hindering their ability to understand and retain complex scientific concepts. Studies have shown that such methods can decrease student interest and motivation in science, leading to lower academic performance. In contrast, according to Makransky and Lilleholt (2018), 3D visualization provides a dynamic platform that enables students to interact and visualize scientific phenomena in a simulated three-dimensional space. This interactive learning environment can close the knowledge gap between theory and practice, improving the efficacy and excitement of learning. Active learning techniques, like inquiry-based learning and hands-on experiments, are more effective in encouraging a deeper understanding of scientific principles by encouraging critical thinking and practical application (Freeman et al., 2014) increasing interest in advanced technology to enrich science education by focusing on more direct interactions. This method could enhance visualization and engagement with complex scientific material. The use of 3D visualization in the classroom has the potential to improve students' understanding of abstract scientific topics by allowing them to explore and interact with models in ways that conventional methods cannot (Chang, Quintana, & Krajcik, 2014). For eighth-grade children, an important period of cognitive and intellectual development, comprehending scientific concepts gets more difficult as concepts become more abstract. Cell biology, molecular structures, chemical reactions, and the Earth's geological processes can be difficult for pupils to understand when taught in traditional ways (Lowe, 2019).

Science is taught using conventional methods such as textbooks and lectures, which often cannot effectively explain complex ideas. Many students, particularly those in elementary grade, can find it difficult to grasp scientific phenomena that cannot be observed directly or easily visualized. Instead of interest and engagement, science can start to feel confused or irrelevant to their everyday lives. As a result, many students may lose interest, which can hinder their overall learning and prevent them from developing a deeper understanding of the subject. This gap is significant in conventional science education, underscoring the need for more effective teaching methods that make complex ideas more accessible and engaging. (Liu, Wang, Koszalka, & Wan, 2022).

3D visualization has emerged as a potential solution to address these challenges by offering immersive, interactive experiences that can make difficult concepts more accessible. National Education Policy (NEP) 2009 focuses on adopting digital tools, such as simulations and visual aids, to enhance science education. However, the impact of 3D visualization on enhancing science education and improving students' conceptual understanding is still an area that requires further exploration. The National Education Policy 2021 and initiatives such as the Pakistan Vision 2025 have called for modernizing the curriculum and adopting ICT-based teaching strategies, including multimedia and digital learning tools, to improve the quality of education (Government of Pakistan, 2021). 3D visualization can significantly enhance students' understanding of difficult concepts, improve academic performance, and sustain their interest in science (Burdea & Coiffet, 2003). Then, find out the use of 3D visualization in science students to understand scientific concepts more easily. The study will focus on the "effect of teaching science through 3D visualization on 8th-grade achievement in science".

This study explores how 3D visualization impacts science education and possibly changes how science is taught and acquired. The study was useful in scientific concepts that are frequently difficult to understand when using conventional methods, especially when teaching elementary school students. The teaching method in Pakistan is textbook-based and focuses on rote memorization rather than conceptual comprehension (Mahmood, 2010). The study was to help understand complex concepts that are difficult for many students to visualize or observe directly can be difficult. The study also intends to investigate the function of 3D visualization in improving student engagement and motivation.

According to research, middle school is an important time for students to develop an interest in science, a lot of students lose interest because of the abstract nature of the content and the perceived difficulty of science topics (DeWitt & Archer, 2015). By making scientific concepts more interactive, clear, and engaging, 3D visualization can reactivate students' interest in science. Increased involvement is an important predictor of long-term interest and success in STEM subjects, making it critical for Pakistan's future workforce growth in science, technology, engineering, and mathematics. This research is important because it can help address these issues by assessing how well 3D visualization can improve science education. 3D visualization has the potential to completely change science education if it can increase students' understanding and engagement. 3D visualization provides engaging and interactive experiences. The study will introduce new methods of teaching in educational institutions. This study will help Pakistan's ongoing efforts to improve science education by providing evidence on the usefulness of 3D visualization in increasing academic achievement, supporting curriculum reform, and fostering more student engagement in science.

3D visualization has been a game-changer in science education because students can obtain a bird's eye view of hard concepts in an interactive, spatially accurate format through this medium. Through 3D visualization, students can see work with and be enchanted with scientific models in virtual spaces offering different than traditional teaching ways. That helps them gain a more profound understanding of abstract concepts and policies. Immersive characteristics of the 3D visualization tool can be reported to yield an experiential learning environment that has been found highly beneficial for retention and achievement in science (Astuti, et al., 2020).

The earlier study confirmed that 3D visualization enhances inquiry-based learning and spatial thinking, majorly in the fields of physics, chemistry, and biology. As a case in point, Liu et al. (2021) concluded that students who were studied traditionally and exposed to biology but associated with 3D visualization in their classes gained an improvement in the cognitive conceptual understanding of their capabilities. Adams et al. have suggested that the incorporation of 3D tools within the chemistry class improves spatial skills along with students' academic performance, that by increasing their abilities in problem-solving.

3D VISUALIZATION

Creating three-dimensional exemplifications of concepts or entities that can be viewed and manipulated from different perspectives in a simulated environment is known as 3D visualization. 3D visualization in education denotes the use of technology to give students interactive genuine experiences that improve their comprehension of difficult thoughts. In contrast to two-dimensional graphics or still images, 3D visualization submerges students in situations that allow them to investigate details, promote spatial awareness, and engage with the substantial in a way that inspires active learning (Liu et al. 2020) moreover use of latest technologies enhance students' all round development (Chudhry & Malik, 2019).

Because it makes abstract or problematic concepts more approachable and interesting 3D visualization is crucial in education chiefly in science. According to studies, 3D visualization critically enhances students' capacity for problem-solving spatial reasoning, and intangible understanding. In science education that is particularly helpful because various phenomena are too small, large, or complex to be directly witnessed. 3D visualization generates an immersive learning environment that is hard to identical with conventional techniques, by enabling students to see biological procedures, physical systems in motion, or molecular structures in chemistry (Berame, et al., 2022). Moreover, studies have proven that students who employ interactive 3D visualization implements can recall information for a longer time than those who only use conventional approaches. This implies that the immersive property of 3D visualization expands retention. This high recall is particularly important for disciplines such as science where concepts typically build on one another. This makes students more effective at applying what they have learned in practical scenarios, making better decisions, and solving problems (Demirezer, & İlkörücü, 2023).

The Role of 3D Visualization in Modern Science Education

Since it crosses the gap between theoretical knowledge and practical understanding, 3D visualization has been very central in science education within a changing landscape. Divergent from two-dimensional representation, 3D visualization offers students a dynamic, engaging capability through which abstract ideas can be turned into something more tangible and understandable. This has made 3D visualization a crucial tool in the refinement of scientific literacy interaction students with simulations and models in ways that enhance their engagement and support more effective learning (Kalemkuş, 2023).

The development of spatial and analytical reasoning is one of the key learning objectives that 3D visualization intends to fill in modern science education. For example, when it comes to planetary systems, chemical reactions or cellular structures, a student can see these ideas right in front of them with the use of 3D models taking the explanation of relationships and procedures to a whole different level. Research by Adams et al. The process of conducting experiments with simulation tools and visualization can improve skills and switch the student's mindset to a place-based learning world thus aiding in better memorization through association with physics, chemistry, and biology concepts (Liu et al. 2020).

Achievement Outcomes of 3D Visualization

The application of 3D visualization in science teaching has led to substantial gains in the academic performance of students by better understanding and remembering difficult ideas. 3D visualization provides an interactive and engaging learning experience that directly impacts academic outcomes, as students can interact with and manipulate scientific models. The students who used 3D visualizations for learning a scientific subject performed better compared to those using the methods applied by their teachers in their teaching. Many meta-analyzing several studies showed some gains both in immediate retention as well as long-term retention (Teplá, et al., 2022). For example, from chemistry, they will become better equipped to understand notions such as molecular geometry or reaction mechanisms that they ought to learn to be able to understand and master key concepts. Adams and colleagues reported that students who used 3D visualization in molecular chemistry learned better on measures of conceptual and spatial understanding and improved problem-solving skills in applying theory to real-life situations. This means that 3D visualization helps the student apply these concepts in myriad contexts, which is of paramount importance for success outside of helping with immediate comprehension (Kul & Berbe, 2022).

COMPARATIVE STUDIES ON TRADITIONAL VS. 3D LEARNING OUTCOMES

The comparative studies with traditional and 3D visualization-based learning methods depicted that students consistently obtained better learning outcomes with science education when 3D visualization is used. When complex spatial and abstract concepts of science are taught under disciplines like biology, chemistry, and physics, the explanations become difficult with traditional resources such as lectures, books, and 2D images. Research studies show that 3D visualization techniques offer more interactive experience than conventional approaches to teaching for the comprehension of knowledge understanding, memory, and practice (Al Amri et al., 2022). The use of traditional 2D models of molecules and atomic structures in chemistry classes could make it difficult for the student to develop spatial awareness that is essential to understanding molecular interactions and reactions. According to Adams, et al. (2023), students who learned chemistry using 3D models performed 30 percent better on average on tests of spatial understanding and reaction prediction compared to students who learned the same subject using conventional methods. This is because 3D visualization enables one to present geometries of intricacy complexity and bond angles. Similarly, with the help of 3D visualization, students of biology can explore cellular structures, anatomical systems, and ecological relationships that cannot be achieved through 2d diagrams and lectures to a certain degree with interactivity. In the comparative study involving biology students who made use of 3D models and those who utilized textbooks and 2D diagrams, the former group improved by 25 percent on test scores regarding topics covered under cellular biology and anatomy. It concluded that students can be allowed to navigate and interact with biological structures through 3D visualization which leads to retention and application of the knowledge (Liu et al. 2020).

THEORETICAL FRAMEWORK

Constructivist Theory and 3D Learning

Using constructivist theory means that students, rather than passively receiving knowledge, build that knowledge through experiences. This theory prescribes a dynamic captivating learning environment that fosters active engagement in learning regarding 3D learning model. Pedagogical opinions that constructivism could be easily backed up with the help of 3D visualization tools along with students' desire to manipulate something tangible while studying non-trivial matters. Simulation in the classroom allows a learner to build their understanding based on the use of experimentation, problem-solving, and inquiry in simulated environments. The constructivist theory forms an important underlying framework since students are likely to retain information better and gain a deeper conceptual understanding when they interact with 3D models and simulations.

Multimedia Learning Theory

Multimedia Learning Theory developed by Richard Mayer (2001). VR integrates multiple forms of media (visual, auditory, interactive) to present scientific concepts. This multimedia approach enhances learning by leveraging dual-channel processing in the brain and reducing cognitive overload. Uses visual and auditory information to enhance understanding and cognitive load by presenting information in a format that supports efficient processing. Increase engagement through interactive and immersive media.

Situated Learning Theory

Situated Learning Theory was developed by Jean Lave and Etienne Wenger (2022). VR creates context-rich, authentic learning environments where students can explore scientific concepts as they would in real-world contexts. This approach helps students understand the relevance and application of what they learn. VR provides realistic simulations that mimic real-world scientific phenomena. Students engage in tasks that reflect actual scientific practices. And facilitates collaboration and discussion in virtual environments that mirror real-world scientific communities.

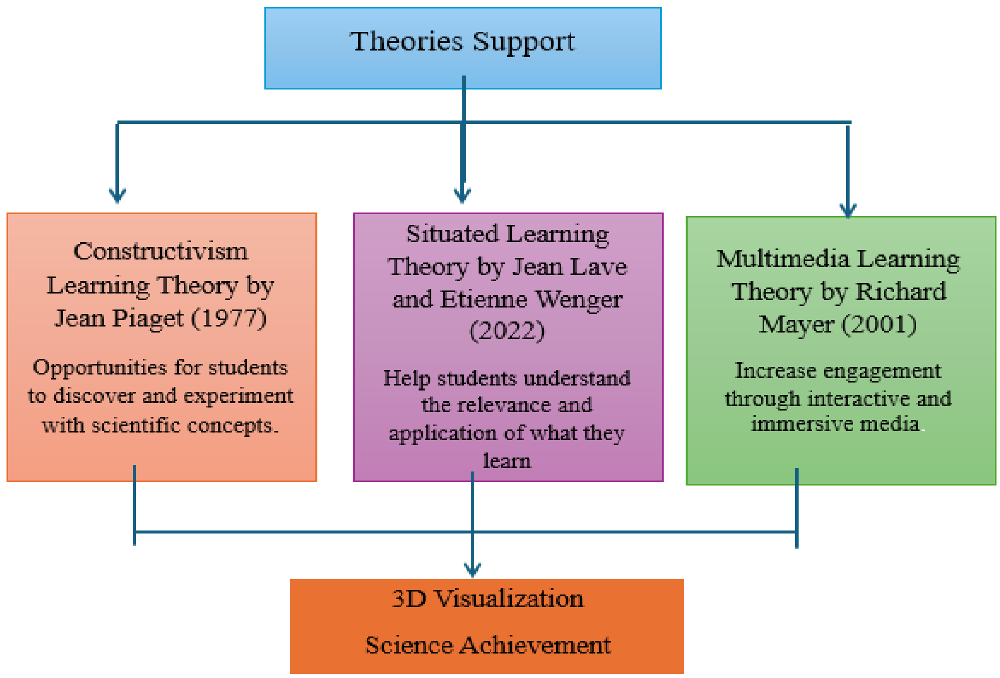

Figure 2.1: Theoretical framework of the study

Conceptual Framework

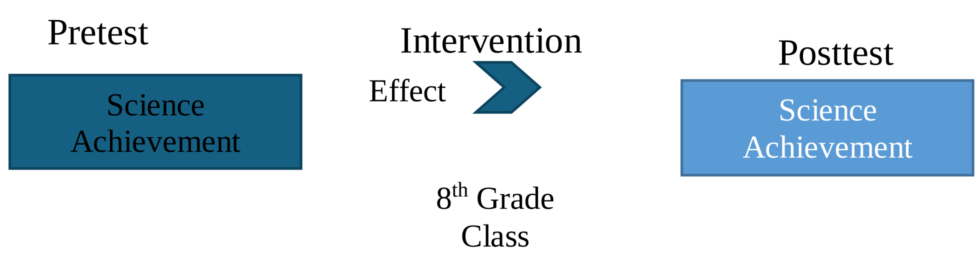

Figure 2.2 Conceptual framework of the study

Objectives of the Study:

The study was based on the following objectives:

- To determine the effect of 3D Visualization on the learning ability to understand the science concepts (human nervous system, cell division, biotechnology, and acid, base, and salts) of grade eight students.

Research Hypothesis:

The following were the research hypotheses of the study:

H_{01}: There is no significant difference in the means of pre-test science achievement test scores of controls and experiment group students.

H_{02}: There is no significant difference between the means of experiments' post-test science achievement test scores and control group students.

H_{03}: There is no significant difference in science achievement scores mean of students pre-test and post-test who were taught through conventional teaching methods.

H_{04}: There is no significant difference between the mean in science achievement scores of students who taught through 3D visualization on pre-test and post-test.

METHODS

The study was quantitative, and the paradigm of this research design was post-positivism. Post-positivism frequently knowledge should be based on observable facts and measured using numbers, which is why it often relies on quantitative methods like surveys and experiments" (Creswell, 2014). The study was following a True experiment in nature. A true experiment is a research design widely recognized for its capacity to establish causality by using strict control and randomization.

Population:

All grade 8 students studying Punjab textbook in public and private sector schools in Lahore were the target population of this research.

Sampling:

A sample of the study school was selected conveniently for this purpose. Permission was sought from the principal of elementary schools. In the selected schools, grade eight students were divided into two groups through matching pairs based on the pre-test results. A student was randomly assigned to each two groups from each pair. On the basis of randomization one group was selected as control and other as an experiment group with 15 students in each group.

Instrumentation:

An achievement test of science was used as pretest and the posttest. The table of specifications was developed to obtain students' science achievement scores; the aim was to ensure that the test included a comprehensive and fair distribution of questions according to blooms taxonomy of learning objectives (Level 1: Knowledge, Level 2: Understanding, Level 3: Application).

Table 1: ***Table of Specification of Science Grade Eight***

Sr. No	Chapters	Percentage	MCQS				Distribution of Marks
1.	Human Nervous System	33%	4	3	3	10	10
2.	Variation, Heredity, Cell division	23%	2	3	2	7	7
3.	Biotechnology	13%	2	1	1	6	6
4.	Acids, Bases and Salts	20%	2	2	2	10	10
	Total	100%	33%	30%	27%	30	30

The table 1 shows the construction table of specialization is 30 marks across 30 multiple-choice questions, with all questions to be attempted within a 40-minute. Each chapter is weighed differently to reflect its importance within the curriculum. The Human Nervous System receives the highest weightage at 33%, contributing 10 marks through questions across all cognitive levels Knowledge (4), Understanding (3), and Application (3) indicating a strong focus on this topic. Variation, Heredity, and

Cell Division are weighed at 23% for 7 marks, emphasizing understanding through 2 Knowledge, 3 Understanding, and 2 Application questions. The Acids, Bases, and Salts chapter, with a 20% weightage and a total of 10 marks, also distributes questions evenly across the three cognitive levels 2 Knowledge, 3 Understanding, and 2 Application. Finally, Biotechnology holds the smallest weightage at 13%, adding 6 marks through 2 Knowledge, 1 Understanding, and 1 Application question. Overall, the assessment prioritizes knowledge (33%), followed by understanding (30%) and application (27%), ensuring a balanced evaluation of students' recall, comprehension, and practical application of concepts.

Intervention and Procedure of the study:

The duration of the intervention was forty days. The control group was taught by the routine school while the experiment group was taught by the researcher. The pre-test and post-test were used to test the science achievement of experimental and control groups. Duration of each test was 40 min. Research used 3D visualization video during the intervention through lesson plans. Researchers used 3d videos for YouTube platform, it was basically the educational purpose that helped children developed their creativity, cognitive thinking. The 3D visualization video was used as a form of intervention will consist of one lesson plan on science (the department of education recommended subject division). Throughout the experimental period, 40 lesson plans were given. A topic was assigned eight days, being used for topic 3D visualization video presentation. SLOs were first chosen and converted into 3d visualization videos. Researcher were used the 3D visualization video platform YouTube channel name "Visual Learning". The chapters of the human nervous system, cell division, biotechnology, Acids and bases by connecting the concept to their everyday experiences, student were inspired to learn more about it.

Through interactive video, students can learn mitosis and meiosis concepts with the help of the Visual Leaning YouTube platform fosters engaging active learning. Because each concept is offered in a range of difficulty, students can begin with easier understand. Real-time feedback is given to students as they advance, boosting their confidence and assisting them in identifying areas for growth. 3D visualization encouraging a love for science by letting students learn and providing enjoyable and significant support for their academic development. Validation of the intervention used in the study was carefully established. The 15 study in the experiment group were given 3D lecturers. The 3D visualization video was specially approved by the school science subject teacher, ensuring that it aligns to the curriculum and learning objectives. The purpose of the intervention was to help students improve basic science concepts. In the end, this sought to enhance students' general understand of abstract science concepts.

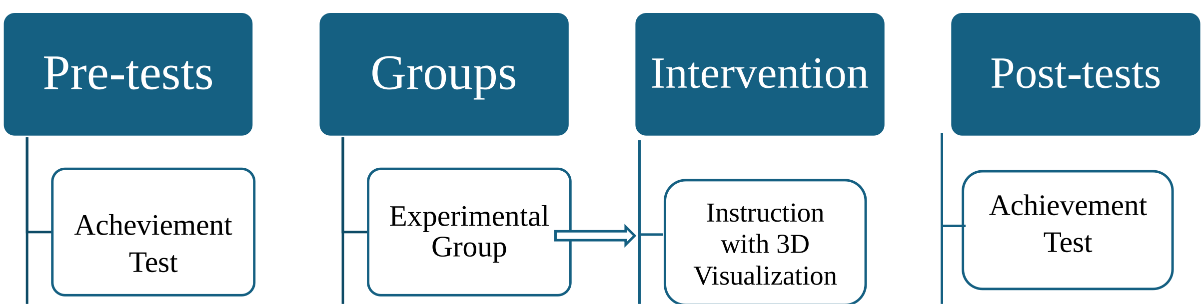

Figure 1 The interventional process of the study

Data Collection Techniques:

Pre and post-tests were administered to participants to measure their science learning, motivation, and anxiety before and after the intervention. The pre and post-tests will cover a range of science concepts relevant to their grades.

Data Analysis Techniques:

After the data collection phase data obtained from science achievement scores were tabulated and analyzed using the statistical package for social science (SPSS). Before the data analysis, the science achievement test was checked for reliability. The reliability value was Cronbach's alpha at 0.87. A paired sample t-test determined the effect of 3D Visualization on student learning ability in the pre-test and post-test. To compare control and experimental groups was used independent t-test. A paired sample t-test checking out the effect of 3D Visualization in science. Item analysis was done to analyze the inconsistency of items of the instrument.

Ethical Considerations:

The researcher informed all the participants before taking pre-test. The researcher obtained approval from the school principal and class teacher to conduct the experiment study. It was clearly told to the students that participation would not affect their grades.

DATA ANALYSIS

Analyzing and interpretation data was done "Effect of teaching science through 3D visualization on 8th grader's achievement in science". To find out how to control and experiment groups different before and after the intervention. Inferential statistics such as independent sample t-test and paired sample t-test were used. Following analysis, the data was displayed in a table along with an explanation.

H_{01}: There is no significant difference in the means of pre-test science achievement test scores of controls and experiment group students.

Table 2: Independent Sample t-test to Identify the Mean Difference in Pre-test Scores of the Control and Experiment Groups.

Variable	**Group**	***N***	***M***	***SD***	***t-value***	***df.***	***p-value***
Science Achievement	Control Group	15	12.67	3.654	.325	28	.748
	Experimental Group	15	12.47	4.190			

The independent samples t-test was conducted to examine if there was a significant difference in science achievement scores between the control and experimental groups before the intervention involving 3D visualization. This null hypothesis was accepted as there was no statistically significant difference in pre-test scores between the two groups, *t (28) =.325, p=.748*. The mean achievement score for the control group *(M = 12.67, SD = 3.654)* was that of the experimental group *(M = 12.47, SD = 4.190)*, however, this difference is not significant, as the p-value is well above the typical significance level of .05. This suggests that both groups started with comparable levels of science achievement before the intervention.

H_{02}: There is no significant difference between the means of experiments' post-test science achievement test scores and control group students.

Table 3: Independent Sample t-test 3D Visualization to Identify the Mean Difference in Scores on Science Achievement Between the Control and Experimental Groups in the Post-test.

Variable	Group	*N*	*M*	*SD*	*t-value*	*df.*	*p-value*
Science Achievement	Control Group	15	12.73	2.321	-13.73	28	.000
	Experimental Group	15	26.20	2.086			

The independent samples t-test results indicate a statistically significant difference in post-test science achievement between the control and experimental groups, with the experimental group showing a much higher mean score *(M = 26.20, SD = 2.08)* compared to the control group *(M = 12.73, SD = 2.32)*. The t-value, *t (28) =−13.73*, and a *p-value* of *p < .05)* suggest that the difference is highly significant. These results imply that the null hypothesis was rejected the 3D visualization intervention substantially impacted the experimental group's achievement in science compared to the control group.

H_{03}: There is no significant difference between the means in science achievement scores of the control group on the pre-test and post-test who were taught through conventional teaching methods.

Table 4: ***A Paired Sample t-test in Science Achievement Scores Between the Pre-test and Post-test in the Control group***

Variable	*M*	*SD*	*t-value*	*df.*	*p-value*
Pre-test	12.67	3.654	.292	14	.774
Post-test	12.73	2.321			

A paired samples t-test showed no meaningful improvement in science achievement within the control group from the pre-test *(M = 12.67, SD = 3.65)* to the post-test *(M = 12.73, SD = 2.32)*, despite no statistically significant result, *t (14) =.292, p <.05*. The null hypothesis was accepted as there is no mean difference in science achievement scores of the control group on pre-test and post-test who were taught through a conventional teaching method.

H_{04}: There is no significant difference between mean scores of students in science achievement who taught through 3D visualization on pre-test and post-test.

Table 5: A Paired Sample t-test Identifies in 3D Visualization the Mean Difference in Science Achievement Between the Pre-test and Post-test in the Experimental Group.

Variable	*M*	*SD*	*t-value*	*df.*	*p-value*
Pre-test	12.47	4.190	-14.10	14	.000
Post-test	26.20	2.086			

The paired samples t-test is a significant increase in science achievement scores within the experimental group from the pre-test *(M = 12.47, SD = 4.190)* to the post-test *(M = 26.20, SD = 2.086)*, with *t (14) =−14.10* and p<.05. This indicates that the null hypothesis was rejected the 3D visualization intervention had a positive impact on student's achievement. There is a significant difference in science achievement which means the scores of students who taught through 3D visualization on pre-test and post-test.

CONCLUSION

Based on the analysis and their findings, it is concluded that 3D visualization was useful tool for science subjects. This experimental research shows that students' science achievement scores increase in experimental groups. Both groups had comparable baseline levels before the intervention, as evidenced by pre-intervention findings showing no significant differences in science achievement between the control and experimental groups. Post-test findings, however, show a clear difference. Based on the first null hypothesis, it conducts the mean difference in science achievement in pre-test scores of controls and experiment groups. This result showed steady performance between control and experimental groups, with equal in science achievement scores, following random selection and grouping of students. The null hypothesis was accepted; there were no differences found in the mean scores of the pre-test between the control and experiment groups.

The second null hypothesis, the effect of 3-D Visualization on the science achievement scores of the control and experimental group, analysis proved that the null hypothesis was rejected there is a statistically significant difference in post-test science achievement between the control and experimental groups. 3D visualization intervention substantially impacted the experimental group's achievement in science compared to the control group.

The third null hypothesis, the mean difference in science achievement scores of the control group on pre-test and post-test who were taught through conventional teaching methods, analysis that the null hypothesis was accepted, there is no mean difference in science achievement scores of the control group on pre-test and post-test who were taught through a conventional teaching method. The fourth null hypothesis, the difference in science achievement, mean scores of students who taught through 3D visualization on pre-test and post-test analysis that indicates that the 3D visualization intervention was a meaningful difference in student achievement. The null hypothesis was rejected the significant difference in science achievement means the scores of students who taught through 3D visualization on pre-test and post-test.

DISCUSSION

Findings from this study indicate that 3D visualization significantly affects students' performance toward science. The experimental group shows a significant improvement in students' science achievement towards science compared to the control group. The result suggests that the increase in the student's science achievement toward science post-test mean scores for the experimental group was due to the significant effects of 3D visualization. Therefore, the study's findings are consistent with the results reported by Zhang and other colleagues' research in 2021 that students who used 3D models performed better in tests of complex systems like an ecosystem and human anatomy. Because 3D visualization is interactive it allows for a hands-on approach with active learning theories and yields increased test scores and comprehension of scientific procedures. Moreover, 3D visualization has been proven to enhance student performance in physics, especially in areas that require high spatial reasoning (Yang & Wang, 2023; Naeem, Ali, & Ahmed, 2022).

Adams and colleagues (2022) reported that students who used 3D visualization in molecular chemistry learned better conceptual and spatial understanding and improved problem-solving skills in applying theory to real-life situations. This means that 3D visualization helps the student understand abstract concepts (Kul & Berbe, 2022; Jabeen, Ali, & Ahmad, 2023). The significant improvement in science achievement scores for students in the experimental group supports the idea that 3D visualization can be useful in a deep understanding of scientific concepts. With the help of 3D visualization, students of biology can explore cellular structures, anatomical systems, and ecological relationships that cannot be achieved through 2d diagrams and lectures to a certain degree with interactivity.

Zhang et al, in a comparative study involving biology students who used 3D models and those who utilized textbooks and 2D diagrams, the former group improved by 25 percent on test scores regarding topics covered under cellular biology and anatomy. The results of this study revealed that students can be allowed to navigate and interact with biological structures through 3D visualization which leads to retention and application of the knowledge (Liu et al. 2020; Ahmad, Sewani, & Channa, 2025). This finding is consistent with Chen and Tsai's (2020) on 3D visualization in science education, over 50 studies pointed out an effect that significantly impacts students' science achievement scores. That is, students who experienced 3-D visualizations scored nearly a standard deviation higher on exams compared to disciplines such as biology, chemistry, and physics where spatial reasoning and the ability to visualize complex structures become important, the analysis found that the impact of 3-D interventions was particularly greater (Imran et al., 2023). This improvement in 3D visualization promotes more comprehensive science understanding and direct academic outcomes. This finding is also consistent students who relate to 3D visualizations report higher levels of intrinsic enthusiasm because they catch science ideas that are more interesting and relevant when they can see them (Teplá, et al., 2022; Thomas, Khan & Ahmad, 2022). This study is also consistent with Barman et al (2023), that an optimistic attitude towards a science learner with increasing confidence for teaching and learning in the 3D visualization will make an effective environment to lead those students who start exploring anything without having any inhibitions. Such students often continue to have a lifelong interest in science and are critical of developing a strong scientific attitude and perhaps inspiring future STEM career directions.

The findings indicated that 3D visualization is a valuable instructional approach, particularly for subjects requiring spatial or structural understanding, such as science (Yang & Wang, 2023). In the current study, the effect of 3D visualization on science achievement was increased, increased to use 3D visualization compared to conventional methods. The results show that 3D visualization is an effective tool for teaching science.

RECOMMENDATIONS

Based on the study findings and conclusion, recommendations are:

- The study results in an advantage the use of 3D visualization. Thus, use this teaching method to enhance science achievement.
- Promote use 3D visualization in the science curriculum, so that subjects like chemistry, biology, and physics are enhanced using this approach to improve conceptual understanding.
- Developed training programs for teachers and students, to improve learning and study these innovations in practice.
- Facilitate collaborative teaching workshops where educators share best practices and effective lesson plans for using 3D visualization.
- Schools and districts should be funding resources for technology, especially in science classrooms, then implementing 3D visualization as all students benefit from this technology.

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