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RESEARCH PAPER

Effectiveness of CGI Animation as an Instructional Method on Students' Performance in Biology at Secondary Level

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ABSTRACT

This study examined the efficacy of computer-generated imagery (CGI) animation as an instructional method on students' performance in biology at the secondary level in Gujranwala District, Pakistan. Furthermore, it examined its effect on attaining elevated and diminished degrees of cognition in biology. Due to the global educational landscape is shifting, replacing traditional lectures with innovative strategies that enhance learning and student engagement, especially in science education. The study employed a pre-test, post-test, control group experimental design. The study population comprised all girl science students from public schools in Gujranwala during the academic session 2024-2025. A test including 40 items was developed to evaluate students' overall achievements in biology, as well as their proficiency in higher and lower-order thinking skills within the subject. The study's findings indicated statistically significant differences at the 0.05 level. This indicated that students instructed with CGI animation exhibit superior performance in biology compared to those educated through traditional instructional methods. The findings indicate that CGI animation positively influenced students' performance in biology, particularly in attaining both higher and lower levels of cognitive processing in the subject. Extensive utilization of CGI animation in high school education is advised.

KEYWORDS Achievement, Biology, Computer-Generated Imagery Animation, Higher-Order Thinking, Instructional Method, Lower-Order Thinking, Students

Introduction

The worldwide educational environment is changing quickly, and there have been noticeable shifts in the approaches taken by educators. Conventional methods, defined by lecture-based approaches, are being supplanted by novel instructional strategies designed to promote significant learning and increase student engagement, especially in scientific disciplines (Onasanya et al., 2010; Ong et al., 2023). These changes address a predominant issue that scientific education has frequently been teacher-centered, prioritizing rote memorization and placing undue emphasis on test performance (Amjad & Malik, 2024; Ezeudu & Obi, 2013). As a result, numerous students regard science as tedious, laden with abstract notions, and detached from their everyday experiences—an impression bolstered by the focus on rote memorization of facts and terminology (Cimer, 2012). Numerous educational tools exist for educators (Beautemps & Bresges, 2021), with video being one of them. Building upon prior research (Ferreira et al., 2021), wherein we selected and classified a collection of video abstracts in Ecology and Environmental Sciences, we engaged in discussions regarding our scientific video with Biology educators. Educators aim to establish dynamic learning environments that foster curiosity, enhance critical thinking, and enable students to recognize the practical applications of scientific

knowledge in their daily lives by integrating technology and employing learner-centered methodologies (Amjad et al., 2024, a, b, c). These initiatives aim to enhance academic achievement while fostering a lasting enthusiasm for the sciences in students, equipping them to confront the difficulties of a swiftly evolving world (Berdiyeva, 2024; Qureshi et al., 2023).

Teaching science transcends mere instructional activities to convey curricular content to students (Amjad et al., 2023, a, b, c). Science education must be proactive and pertinent to contemporary contexts to prepare students for current and future changes and difficulties adequately. Teaching Science must cultivate and enhance higher-order thinking skills, inquiry skills, critical thinking skills, creativity, and problem-solving abilities. The complexity of learning science arises from its substance, which encompasses abstractions, challenging concepts, laws, and theoretical things that are neither visible nor tangible. Much of scientific education focuses on comprehending predominantly imperceptible processes that are not readily observable due to their minuscule size, sluggish pace, or extensive scale (Shafqat & Amjad, 2024; Wishart, 2014). This is why it is imperative to instruct science in a manner that guarantees all students' comprehension of these processes.

This study aims to assess the effectiveness of CGI animation in improving secondary-level Biology performance. It focuses on enhancing lower-order skills like recall and comprehension and higher-order skills such as analysis and evaluation in ninth-class students. The goal is to determine its advantages over traditional methods in fostering both lower and higher cognitive abilities. The study hypothesizes that CGI animation does not significantly enhance academic performance in secondary-level biology (H01). It also posits that CGI animation does not substantially improve the attainment of lower-order thinking skills, such as recall, comprehension and application, among ninth-class students (H02). Additionally, it suggests that CGI animation does not markedly enhance the development of higher-order thinking skills, including analysis, synthesis and evaluation, in the same student group (H03).

Literature Review

The extensive range of educational materials includes various tools such as audiovisual aids, visual aids, real-world objects, and animation approaches. In addition to conventional mediums like books and films, animation techniques serve as a powerful tool for enhancing educational settings. These dynamic pedagogical tools enhance students' memorization skills and have the capacity to motivate and elevate their academic performance (Khany & Kamalvand, 2022; Tabbasam et al., 2023; Tabassum et al., 2024).

Mayer and Moreno (2002) characterized instructional animations as representations of processes or concepts utilizing computer-generated drawings, graphics, or photographic depictions of things, including puppet models. Howie and Blignaut (2009) contended that animations facilitated learning and were effective in cultivating higher-order skills, including critical thinking, analysis, and scientific inquiry. Buckley and Quellmalz (2013) assert that technological improvements have facilitated the extensive utilization of animation software as educational tools, hence enhancing virtual practical investigations. Aremu and Sangodoyin (2010) examined the impact of computer animation on the academic performance of Nigerian senior secondary school students in biology. The study employed a pretest-posttest, control group, quasi-experimental design. The findings indicate a substantial main effect of treatment on students' achievement in biology, demonstrating that computer animation effectively enhanced students' performance. In their study examining the impact of animation on students' accomplishment and retention

in Basic Electricity at Technical Colleges in Benue State, Numgwo et al. (2017) assessed student performance following exposure to both animation instructional techniques and conventional teaching methods. The study's findings indicated that students instructed using animation exhibit superior achievement and retention in Basic Electricity compared to those taught via conventional methods.

In a separate study, Goff et al. (2016) examined the efficacy of an online meiosis learning module as an independent educational resource. They conducted an experiment with participants enrolled in an introductory biology course on meiosis, assigning them to one of two conditions: the interactive learning module or a conventional lecture session. Analysis of student accomplishment indicated that students who saw the learning module as their sole method of conceptual presentation had considerably higher scores than those who solely attended a standard lecture on the subject. Their findings indicated that the animation-based learning module effectively communicated the concepts of meiosis, suggesting it may enhance student learning beyond the classroom. Furthermore, these findings hold significance for educators aiming to enhance their repertoire of strategies for "flipping" undergraduate biology courses.

In the 21st century, a technology-enhanced educational system is essential for significant learning experiences. Technologies including computer-aided learning, computer-based training, and multimedia applications have transformed education (Rajaram, 2021). Among these advances, Animated Instructional Material emerges as a dynamic approach that integrates computer animation, graphics, and cartoons to augment classroom learning (Yulianti et al., 2021).

Ikwuka and Samuel (2017) demonstrated in their study on the impact of computer animation on chemistry achievement that students instructed with computer animation Chemistry instruction (CACI) yielded superior academic accomplishment in Chemistry compared to students instructed by conventional methods (CM). Their explanation indicated that this disparity may stem from the CACI's capacity to deliver auditory and visual representations of the experimental methods and the microscopic notions that were previously conceptualized and are now rendered visible by CACI. They contended that CACI can enhance student learning, as enjoyment and pleasure are inherent methods of learning, hence augmenting student performance.

Students frequently interpret animation characteristics literally, resulting in a misapprehension of the information conveyed in the animation. Moreover, students endeavor to elucidate their observations by employing their past knowledge, which may be erroneous or misapplied. The instructional application of animations and visualizations necessitates accompanying pre- and post-explanations and conversations to rectify misrepresentations. A robust core understanding equips students to comprehend and retain structural and procedural concepts presented through animations.

Daly et al. (2016) examined the efficacy of animated visuals compared to static images by producing two iterations of a 4-minute multimedia presentation on vascular neuro effector transmission for undergraduate students in pharmacology and physiology. The results indicated that although student feedback was overwhelmingly positive, leading to heightened satisfaction, there was insufficient evidence to support the superiority of animated images over still images. In this specific format, the difference was not statistically significant when comparing one version that included narration and animations to another that featured narration and still images. The researchers determined that the utilization of intricate multimedia instructional films requires additional

investigation, as neglecting cognitive load and multimedia theories in their design may undermine their efficacy as educational tools.

Kidwai et al. (2017) examined the impact of visual scaffolding and animation on students' performance in higher-order learning assessments. The analysis results demonstrated that distinct forms of visual scaffolding (simple and complicated) are significant factors in enhancing particular performance outcomes. The preliminary analysis of the results suggested that specifically designed and implemented visual scaffolding strategies can enhance procedural understanding and alleviate the cognitive load linked to advanced processing levels in knowledge acquisition. The Pakistani educational system has traditionally prioritized rote testing, resulting in superficial learning and obstructing genuine knowledge development. Educators, cognizant of students ' restricted understanding, confronted the difficulty of instilling critical thinking skills to establish a robust foundation prior to progressing to intricate subjects (Shukla & Dungsungnoen, 2016). The findings of an initial study demonstrated that animation significantly influences the acquisition of factual and conceptual knowledge. Empirical research is required to comprehend the influence of CGI animation on learning. This study sought to compare CGI animation with conventional teaching methods in secondary-level biology. The research aimed to offer valuable insights into the effective integration of technology in scientific education in Pakistan by analyzing student achievement and learning outcomes.

During her tenure teaching biology at the secondary level, the researcher observed students ' inadequate performance on assessments, particularly those evaluating higher-order thinking as delineated in Bloom's taxonomy of learning domains. This may be attributed to the abstract nature of certain biological concepts, which students find challenging to comprehend, coupled with their insufficient foundational scientific understanding. This compels educators to seek educational ways that facilitate students ' attainment of various biology outcomes. In light of the contradictory research findings about the use of animations to enhance student achievement, this study aims to examine the effectiveness of CGI animation as an instructional method for improving secondary-level students' performance in biology.

Material and Methods

It was a quantitative research study that adopted an experimental approach within the framework of a positivistic paradigm. To minimize potential issues with the accuracy of the research findings, the researcher used the pretest-posttest control group design. In this study, two groups (control and experimental) were fairly matched through random sampling. The independent variable was the teaching strategy (use of CGI animation and traditional teaching method). The dependent variable was the performance in biology. This research was restricted to a purposefully chosen sample of 9th class biology girl students during the academic year 2024–2025 at the Government Girls High School in Gujranwala. The sample comprised 60 girl students.

The target population of the present study consists of all the public high schools' science (Biology) students in Gujranwala. The accessible population of the present study will be 9th class students from girls public school of Gujranwala. The study participants' were selected from the Government Girls High School in Gujranwala ninth class students which studying biology. The researcher used the random sampling for the distribution of the students in the two groups: control and experimental, where the experimental group and taught using the CGI animation method, while the control group and taught using the traditional teaching method. In this study, two groups (control and experimental) were

fairly matched through random sampling. Table (1) shows the distribution of study participants' in the experimental and control group.

Table 1
The sample distribution according to groups (experimental, control)

Group	Instructional Method	Number of Students
Experimental Group	CGI Animation	30
Control Group	Traditional teaching	30
Total		60

The researcher developed a 40-question accomplished test aligned with the 9th-class curriculum to assess proficiency and thinking skills. Validity was ensured through expert reviews and a pilot study, while reliability was confirmed with a Kuder-Richardson Formula 20 coefficient of 0.809. Table (2) illustrated the distribution of the accomplishment test based on the cognitive levels assessed by the exam.

Table 2
Distribution of test items according to the cognitive orders of thinking skills measured by the test

Cognitive Orders	MCQs items	Marks
Low-orders Thinking skills	30	30
High-orders Thinking skills	10	10
Performance core	40	40

To address the study questions and evaluate hypotheses, averages and standard deviations of the students ' scores in the experimental and control groups were computed for both pre- and post-application of the instrument. Differential and inferential statistics were utilized to analyze the gathered data values. Data were inputted into the statistical analysis. Mean scores were computed, and independent t-tests were utilized in the inferential statistics procedure. The mean score differences between the pretest and posttest for both groups, together with the standard deviation, mean value, and t-value, were employed to compare and analyze the test scores of the two groups. Statistical significance was ultimately evaluated using the independent t-test to compare mean scores between two groups.

Results and Discussion

Findings of the study concerning the primary purpose "To ascertain the impact of CGI animation on enhancing academic performance in biology at the secondary level." The subsequent hypothesis derived from this objective is: "H01. CGI animation exerted no significant influence on enhancing achievement in biology at the secondary level." To evaluate this hypothesis, the averages and standard deviations of the students ' scores in the two groups—experimental (utilizing CGI animation) and control (employing the traditional method)—were computed for both the pre- and post-assessments of the comprehensive biology accomplishment test (Table 3).

Table 3
The analysis of the pre and post-application of the accomplishment test in biology for experimental and control groups.

Test	Control Group (N=30)					Experimental Group (N=30)				
	Means	SD	t-value	Df	p-value	Means	SD	t-value	df	p-value
Pre-test	18.47	4.08				18.45	4.05			
Post-test	20.00	4.14	1.916	29	0.65	48.47	2.14	37.79	29	.000

Table (3) indicated that the mean post-test score for the control group was 20.00, with a standard deviation of 4.14. The mean pre-test score of the control group was 18.47, with a standard deviation of 4.08. The calculated t-value for degrees of freedom 29 was

1.916. The experimental group's post-test mean score was 48.47, with a standard deviation of 2.14, indicating that the data points are closely clustered around the mean. The mean of the experimental group's pre-test was 18.45, with a standard deviation of 4.05, indicating a broader dispersion of data points throughout a range of values. The calculated t-value for df 29 was 37.79, but the tabulated value was 2.05, which did not exceed the t-value at the 0.05 significance level. The estimated t-value was less than the table value, resulting in the rejection of H01. It was suggested that a disparity existed between the mean scores of the students in the experimental and control groups in the pre- and post-test findings. Consequently, a disparity in means was seen between the two groups on the biology accomplishment test. This aligns with the conclusions of Aremu & Sangodoyin (2010), which demonstrated that computer animation effectively enhanced student achievement, as well as the findings of Numgwo et al. (2017) and Ikwuka & Samuel (2017). Findings of the study concerning the second objective: "To evaluate the effect of CGI animation on improving lower-order thinking skills in biology among ninth-class students." The subsequent hypothesis derived from this aim is: "H02. CGI animation did not significantly improve the attainment of lower-order thinking skills in biology among 9th-class students." To evaluate this hypothesis, the averages and standard deviations of the students' scores in the experimental and control groups were computed for both pre- and post-assessments on the lower cognitive orders of the biology accomplishment test. The corrected mean scores were computed, and a t-test was conducted (Table 4).

Table 4
The experimental and control groups analysis of the pre and post-application on the lower order thinking skills of the accomplishment test in biology.

Group	Pre-test						Post-test				
	N	Means	SD	t-value	Df	p-value	Means	SD	t-value	Df	p-value
Control Group	30	3.73	1.701	-0.526	58	-0.526 <2.00	4.73	1.856	16.301	58	.000
Experimental Group	30	4.13	1.813				9.47	1.167			

Table (4) presented the aggregate mean of the pre- and post-test scores for both the control and experimental groups. The mean pre-test scores for the control and experimental groups were 3.73 and 4.13, respectively, with standard deviations of 1.701 and 1.813, respectively. The calculated t-value for degrees of freedom 58 was -0.526. The control group's post-test mean was 4.73, with a standard deviation of 1.856, indicating a broader dispersion of data points. The mean post-test score for the experimental group was 9.47, with a standard deviation of 1.167. The calculated t-value for df 58 was 16.301, while the tabulated value was 2.00, which was not exceeded by the t-value at the 0.05 significance level. The estimated t-value was less than the table value, hence H02 was discarded. It was suggested that a disparity existed between the mean scores of students in the experimental and control groups regarding the pre and post-test outcomes of lower-order thinking on the biology achievement test.

Findings of the research concerning the third objective: "To measure the influence of CGI animation on enhancing higher-order thinking skills in biology among ninth-class students." The subsequent hypothesis derived from this objective is: "H03.CGI animation did not significantly enhance the attainment of higher-order thinking in biology among 9th-class students." To evaluate this hypothesis, the averages and standard deviations of the students ' scores in the experimental and control groups were computed for both pre- and post-assessments of higher-order thinking skills in the biology accomplishment test. The corrected mean scores were computed, and a t-test was conducted (Table 5).

Table 5
The experimental and control groups analysis of the pre and post-application on the higher order thinking skills of the accomplishment test in biology.

Group	Pre-test						Post-test				
	N	Means	SD	t-value	Df	p-value	Means	SD	t-value	Df	p-value
Control Group	30	2.53	1.501	1.00	58	1.00 <2.00	3.63	1.731	18.64	58	.000
Experimental Group	30	3.83	1.773				9.87	0.507			

Table (5) presented the aggregate mean of the pre- and post-test scores for both the control and experimental groups. The mean pre-test scores for the control and experimental groups were 2.53 and 3.83, respectively, with standard deviations of 1.501 and 1.773, respectively. The calculated t-value for degrees of freedom 58 was 1.00. The control group's post-test mean was 3.63, with a standard deviation of 1.731, indicating a broader dispersion of data points throughout a range of values. The experimental group's post-test mean was 9.87, with a standard deviation of 0.507. The calculated t-value for df 58 was 18.644, but the tabulated value was 2.00, which did not exceed the t-value at the 0.05 significance level. The estimated t-value was less than the table value, hence H03 was rejected. It was suggested that a disparity existed between the mean scores of students in the experimental and control groups regarding the pre and post-test outcomes of higher-order thinking skills in the biology accomplishment test. The findings align with Younis (2017), which demonstrated that scientific inquiry simulations surpass scientific inquiry activities in fostering higher-order thinking skills.

Summarizing, pre-test results showed no significant difference between the experimental and control groups, indicating similar prior knowledge. However, CGI animation enhanced Biology performance more effectively than traditional methods. The experimental group demonstrated better comprehension, retention, and cognitive skills, excelling in both basic and higher-order tasks like problem-solving and critical analysis.

Conclusion

Based on the results obtained from this research, it had been proven clearly that CGI animation had effectively improved student's achievement in biology. Results of the statistical analysis showed that a significant difference exist in the mean scores of *student*s in the control and experimental groups on the achievement test in biology as a whole, and on the lower and higher levels of thinking of the achievement test in biology. This implied that CGI animation was a worthwhile instructional method for improving *student*s' achievement and the achievement of higher and lower levels of thinking. It is therefore imperative to Adopt CGI animation as an instructional technique in teacher training institutions so that teachers at secondary level should acquire the necessary skills needed for classroom development and presentation of animation, thereby contributing to higher achievement levels of their students. Based on the findings, researchers recommend incorporating CGI animation more frequently in secondary Biology education to improve comprehension of abstract concepts. Training science teachers in developing and utilizing animation as a teaching tool, researching its impact on creative thinking, and integrating CGI into teacher training programs are also suggested for effective classroom engagement.

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