IMPACT OF COMPUTER SIMULATION IN THE BIOLOGY CLASSROOM

Dr. Vinod Kumar Kanvaria
Associate Professor, Department of Education, University of Delhi, Delhi
vinodpr111@gmail.com

Gunjan
M.Ed. Student, Department of Education, University of Delhi, Delhi
gunjansagar21@gmail.com

ABSTRACT
This study aimed to examine the impact of computer simulation on the academic performance of secondary biology students. Conducted within authentic biology classroom settings, it involved a comparative analysis between treatment and control groups, utilizing a quantitative research approach. Two secondary schools in the Pilibhit district were selected, with one designated as the treatment group, integrating computer simulation, and the other as the control group, employing traditional teaching methods. Sixty students (30 from each school's Biology class) participated in the study, undertaking the Biology Achievement Test to assess the influence of computer simulation on their academic performance. Findings revealed significantly higher mean gains among participants in the treatment group compared to those in the control group, indicative of the positive impact of computer simulation on learning outcomes. Statistical analysis further confirmed a notable disparity in mean values between the experimental and control groups, with the treatment group demonstrating clear benefits. Consequently, the study suggests that incorporating computer simulations into traditional biology instruction holds considerable potential to enhance secondary biology education.
Keywords: Computer-simulation, traditional methods, biology classroom, secondary schools.

Introduction

The cultivation of imaginative and creative minds is one of the main goals of science education. The fact that biology studies nature as it is distinguishing it from other science disciplines like chemistry, physics, and mathematics. Therefore, it calls for both theory and a thorough understanding of all biological ideas. Research shows that even after the school day is over, many secondary students still don't fully comprehend plant tissue systems and related fundamental concepts of plant physiology. These are some topics ranked close to the top of the list that are challenging for students to understand and/or for teachers to teach. Therefore, there is a pressing need for innovative teaching strategies that might advance realism in this field.

In contemporary science education, the integration of computer simulations has become commonplace, facilitated by the widespread availability of computing devices such as smartboards and mobile technology, alongside the accessibility of simulation resources across various scientific disciplines, exemplified by platforms like PhET simulations (PhET Interactive Simulations, 2011). This proliferation prompts an inquiry into the optimal utilization of simulations to augment science instruction. Wellington (2004) posits that computer simulation stands as a highly effective pedagogical tool, yielding favorable educational outcomes within science classrooms. De Jong and van Joolingen (1998) define computer simulation as a program housing a model of a system or process, whether natural or artificial, thereby expanding the possibilities for enhanced learning experiences in scientific domains (Akpan, 2001). By actively engaging students in exploration and discovery, computer simulations have demonstrated efficacy as instructional aids, leveraging experiential learning to foster deeper understanding compared to passive modes of instruction (Akpan, 2001).

The transformative potential of computer simulations in biology education is underscored by Nireti, Morenike, and Joyce (2014), who highlight their capacity to positively influence students' attitudes towards biology while serving as effective teaching instruments in classroom settings. Additionally, Guy and Lownes-Jackson (2015) assert that computer simulations stimulate student interest and active participation, bolster memory retention, and afford opportunities for affective and behavioral learning, further reinforcing their pedagogical value. In sum, the strategic integration of computer simulations holds promise for enriching science education by offering immersive and interactive learning experiences that resonate with contemporary pedagogical paradigms.

Computer simulations offer a multifaceted approach that surpasses the limitations of traditional methods by providing dynamic, visually compelling representations, particularly beneficial in illustrating the intricate dynamics of plant tissue systems. Given these advantages, computer simulations hold significant promise as a pedagogical tool for teaching plant tissue systems within the realm of school biology. To address these pedagogical potentials, the study outlined in this paper was formulated to investigate the impact of computer-mediated simulations on students' academic performance, perceptions of the biology classroom, and attitudes toward the subject matter.

Educators may opt to integrate computer simulations into their teaching practices for several reasons. These include efficiency gains, as simulations reduce the time required for setting up and overseeing experimental setups. Additionally, the flexibility inherent in simulations facilitates rapid hypothesis formulation and testing by enabling swift manipulation of experimental variables. Moreover, the availability of diverse visual aids, such as graphs and diagrams, enhances comprehension and aids in conceptual understanding (Blake & Scanlon, 2007).

Research problem

Are there significant differences in learning outcomes between students who experience traditional teaching methods versus those exposed to a curriculum enriched with computer simulations?

Significance of research

- Educational institutions commonly allocate resources towards educational technology initiatives. The outcomes of this study, which assesses the comparative efficacy of digital simulations versus conventional methodologies in enhancing student outcomes, offer valuable insights for optimizing resource allocation strategies.
- Empirical evidence from the study underscores the positive impact of computer simulations on student engagement and enthusiasm in the learning process. This substantiates the case for integrating such technologies into educational frameworks to enhance overall learning experiences.
- The study outcomes serve as a significant resource for policymakers and educators seeking to gauge the efficacy of computer simulations in enhancing student learning outcomes. Informed decisions pertaining to curriculum design and the integration of technology within educational contexts can be better formulated with the insights garnered from this research.

Objectives of research

- The primary objective is to evaluate the impact of computer simulations on students' comprehension of complex biological concepts.
- The study aims to scrutinize disparities in learning outcomes between cohorts utilizing computer simulations and those employing conventional pedagogical methods.
- An integral aspect of the investigation involves assessing the levels of motivation and engagement exhibited by students within biology classrooms facilitated by computer simulations.
- The study seeks to explore the potential of computer simulations in fostering long-term retention of biological concepts among students.

Hypotheses of research

1. There exists no statistically noteworthy variance in the academic achievement of students within the treatment group from the pre-test to the post-implementation assessment subsequent to their exposure to the topic via computer simulation.
2. No statistically significant disparities are evident in the pre-test and post-implementation achievement scores of the control group students following their instruction utilizing traditional teaching methodologies.
3. The analysis reveals no statistically significant discrepancies in the post-implementation achievement scores between the treatment group students, who were instructed using computer simulations, and the control group students, who underwent traditional teaching methodologies.

Literature review

Sr. No.	Paper	Insights
1	Lara, K., Smetana., Randy, L., Bell. (2012). Computer	The document provided does not

	Simulations to Support Science Instruction and Learning: A critical review of the literature. International Journal of Science Education, doi: 10.1080/09500693.2011.605182	specifically delve into the direct influence of computer simulations within the biology classroom. Instead, it centers on the broader efficacy of computer simulations as a tool for enhancing science education and learning outcomes across various contexts.
2	Tomáš, Helikar., Christine, E., Cutucache., Lauren, M., Dahlquist., Tyler, A., Herek., Joshua, J., Larson., Jim, A., Rogers. (2015). Integrating Interactive Computational Modeling in Biology Curricula. PLOS Computational Biology, doi: 10.1371/JOURNAL.PCBI.1004131	In this paper emphasis is placed on the utilization of the Cell Collective platform as an instructional resource aimed at augmenting student engagement and comprehension in biology coursework. It posits that computational modeling and software applications offer novel avenues for pedagogical innovation within biology education.
3	Tahir, Atici., Ahmet, Gökmen., Tuğba, Tafli. (2016). Application and evaluation of biology laboratory experiments with computer-based digital experimental tools. journal of new results in science, doi: 10.14687/JHS.V13I3.3953	The document explores the utilization of computer-based digital experimental tools within biology laboratories and their potential impact on students' self-efficacy and attitudes towards science learning. Notably, it does not singularly focus on the specific implications of computer simulation within the educational landscape of biology classrooms.
4	Orna, Zeira. (2016). Computerized Simulation as a Meaningful Learning Factor in Biology Teaching. American Journal of Educational Research, doi: 10.12691/EDUCATION-4-10-8	The paper delves into the integration of computer simulation as a teaching methodology within biology lessons, citing its potential to enhance students' mastery of content and analytical skills, particularly in modules such as "The Immune System - Models and Simulation." However, it does not exclusively address the ramifications of computer simulation within the broader educational framework of biology classrooms.
5	Hillary, Swanson., Gabriella, Anton., Connor, Bain., Michael, S., Horn., Uriel, J, Wilensky. (2017). Computational thinking in science classroom.	The document investigates the effects of a computationally-enriched science curriculum on students' development of computational thinking practices within a biology classroom setting. Nevertheless, it does not explicitly examine the isolated impact of computer simulation within the educational domain.
6	Dhanush, Kumar., Pratheeksha, Subramanyan., Amitha, Prasad., Athira, Kaimal., Aiswarya, Santhosh., Bipin, G., Nair., Krishnashree, Achuthan., Shyam, Diwakar. (2018). Mathematical Models as Bioscience Educational Informatics Tools. doi: 10.1109/ICACCI.2018.8554810	The document offers insights into various facets of utilizing computer simulations within bioscience education, particularly through the integration of mathematical models as virtual laboratories. However, it does not explicitly delve into the specific implications of computer simulation within the confines of the biology classroom.
7	Gavin, A., Buxton. (2018). Mathematical Modelling and Computer Simulations in Undergraduate Biology Education. Spreadsheets in Education,	The paper explores the role of computer simulations in undergraduate biology education, highlighting their significance in acquainting students with mathematical

		modeling and computational thinking methodologies.
8	Erin, N., Bodine., Robert, M., Panoff., Eberhard, O., Voit., Anton, E., Weisstein. (2020). Agent-Based Modeling and Simulation in Mathematics and Biology Education.. Bulletin of Mathematical Biology, doi: 10.1007/S11538-020-00778-Z	The document discusses the utilization of agent-based models (ABMs) as potent tools for modeling, applicable across both biology and mathematics classrooms. Nevertheless, it does not directly tackle the ramifications of computer simulation within the specific context of the biology classroom.
9	Julian, Fischer., Nils, Machts., Till, Bruckermann., Jens, Möller., Ute, Harms. (2022). The Simulated Classroom Biology - A simulated classroom environment for capturing the action-oriented professional knowledge of pre-service teachers about evolution. Journal of Computer Assisted Learning, doi: 10.1111/jcal.12718	The paper outlines the development of Simulated Classroom Biology (SCRBio), a simulated learning environment designed to evaluate pre-service biology teachers' pedagogical content knowledge (PCK) concerning evolution. Notably, it does not expound upon the impact of computer simulation within the educational framework of biology classrooms.
10	Hongxia, Li., Aidong, Fang. (2022). The Application of Computer Virtual Simulation Technology in General Biological Experiment Teaching. doi: 10.1145/3582580.3582599	The document addresses the application of computer virtual simulation technology within experimental teaching in general biology. However, it refrains from specifically addressing the implications of computer simulation within the educational domain of biology classrooms.

Methodology

Research design

This research adopts a quantitative approach within a quasi-experimental framework, incorporating factors such as dependent and independent variables along with measurement mechanisms. The independent variables in this study encompass computer simulation-based learning and traditional teaching methods, while the dependent variables pertain to the academic achievement and retention of biological concepts among students.

Sample selection

The trial took place in two schools within the Pilibhit district, with one designated as the treatment group exposed to computer simulation and the other as the control group receiving instruction through traditional teaching methodologies. Utilizing a random sampling technique, a total of 60 ninth-grade biology students (30 from each school) were selected from the accessible population to participate in the study.

Tools and tool development

The research employed pre- and post-tests utilizing the Biology Achievement Test, which comprised two written exams created by the researcher. Each exam consisted of 50 multiple-choice questions (MCQs) covering topics presented in classes across the experimental (computer simulation-exposed) and control groups (utilizing traditional teaching methods). Four possible answers were provided for each question, with a maximum score of 50 for both assessments. The instrument underwent validation by five professionals experienced in teaching biology at the secondary level. The primary objective of the study was to gather quantitative data to impartially evaluate the impact of computer simulation on student learning outcomes.

Data collection method

The research instrument utilized in this study, the Biology Achievement Test (BAT), served as a robust tool for data collection. Given the experimental nature of the study, employing both pre- and post-test designs was deemed appropriate. Prior to instruction on the designated topic, a pre-test was administered to assess baseline knowledge across both control and treatment groups.

Following instruction, a post-achievement test was promptly administered to students in both the control and treatment groups, who were taught the same topic through traditional teaching methods and computer simulations, respectively. This post-test aimed to evaluate and juxtapose the learning outcomes between the two groups.

Data analysis technique

To ascertain variance between pre- and post-test mean scores within each group, the t-test was utilized. Both paired and unpaired samples t-tests were employed for data analysis, with a significance level set at $p < 0.05$, ensuring a confidence level of 95%.

Results

Presentation of findings

The Biological Achievement Test (BAT) was administered to a total of 60 students drawn from two distinct schools: 30 students from a school exposed to computer simulation comprised the treatment group, while another 30 students from a separate school served as the control group, instructed via traditional methods.

Table 1 delineates the specific analytical approaches applied to address each of the study's research questions.

No.	Research question	Data analysis technique
1.	Is there any difference in treatment group students' achievement between the pre-test and post achievement test after learning the topic with computer simulation?	Paired Samples t-test
2.	Is there any difference between the pre-test and post achievement test scores of the control group students after learning the topic with traditional teaching methods?	Paired Samples t-test
3.	Are there any differences in the post achievement test scores between the treatment group students who learnt with computer simulation and control group students who learnt with traditional teaching methods ?	Unpaired samples t-test

Table 1: Scientific methods used for the analysis

Data analysis and interpretation

Group	Test	n	mean	SD	t-test	df
Computer Simulation (treatment group)	**Pre-test**	30	25.83	4.04	2.65223E-12	59
	Post-test	30	38.36	4.17		

Table 2: Results of paired samples t-test for treatment group

In Table 2, the pre- and post-test results of students within the treatment group are juxtaposed, with analysis conducted utilizing a paired t-test. The resulting significant p-value of 2.65223E-12, well below 0.05, underscores an observed mean difference of 12.53, indicative of notable enhancement in students' academic performance facilitated by computer simulations.

Group	Test	n	mean	SD	t-test	df
Traditional method (control group)	**Pre-test**	30	23.33	5.59	7.21102E-11	59

Traditional method (control group)	**Post-test**	30	30.36	4.21		

Table 3: Results of paired samples t-test for control group

In Table 3, a comparison between the pre- and post-test scores of students within the control group is presented, with analysis conducted utilizing a paired t-test. The obtained p-value of 7.21102E-11, indicating significance below the 0.05 threshold, suggests a meaningful increase in student achievement, evidenced by a mean difference of 7.03. This implies a positive influence on academic performance resulting from conventional teaching methodologies.

Groups	Test	n	mean	SD	t-test	df
Computer Simulation (treatment group)	**Post-test**	30	38.36	4.17	6.51437E-10	59
Traditional method (control group)	**Post-test**	30	30.36	4.21		

Table 4: Results of unpaired samples t-test for both group

Moving to Table 4, a comparison of post-test results between students in the treatment and control groups is provided. An unpaired t-test was utilized for analysis, yielding a significant p-value of 6.51437E-10, indicative of a notable disparity between the post-test achievement scores of the treatment group and those of the control group. Notably, the treatment group, as evidenced by a mean difference of 8.0, exhibited superior performance, suggesting the efficacy of employing computer simulations for instruction within Biology classrooms.

Support for the research questions or hypotheses

H1-Regarding the hypothesis (H1) concerning the absence of a significant difference in achievement among treatment group students between pre-test and post-achievement tests following instruction with computer simulations, the null hypothesis was rejected. Consequently, a substantial disparity in achievement among treatment group students between pre-test and post-achievement tests subsequent to instruction with computer simulations was confirmed.

To investigate further, a paired sample t-test was employed to analyze pre-test and post-achievement test outcomes for treatment group students. Results from this analysis revealed a significant difference in academic performance, indicating enhanced achievement among students who received instruction utilizing computer simulations. Detailed outcomes of the paired sample t-test for treatment group students are outlined in Table 2.

Table 2 illustrates that post-achievement test mean scores for treatment group students utilizing computer simulations were significantly higher than their pre-test results, underscoring the efficacy of computer simulations in bolstering student performance, comprehension, and biological proficiency.

H2- Assessing the discrepancy between pre-test and post-achievement test scores within the control group following instruction with traditional teaching methods, our null hypothesis stipulating no significant difference was dismissed, as evidenced by the paired t-test yielding a p-value below the predetermined significance level of 0.05. Thus, a notable disparity between pre- and post-achievement test scores among control group students emerged subsequent to instruction with traditional teaching methods. This hypothesis was rigorously evaluated via a paired samples t-test, elucidating the distinctiveness in achievement levels within the control group across the two testing instances. Detailed findings of this analysis are delineated in Table 3, underscoring the notable improvement in post-test mean scores relative to their pre-test counterparts. Consequently, it can be inferred that traditional teaching approaches not only facilitated better comprehension but also enhanced overall performance among students.

H3- Exploring the variance in post-achievement test scores between treatment group students, who received instruction via computer simulation, and their counterparts in the control group, instructed using traditional teaching methods, our null hypothesis positing no significant differences was invalidated, as denoted by the unpaired t-test returning a p-value below the predefined significance threshold of 0.05. Thus, a discernible dissimilarity in post-achievement test scores between the treatment and control groups surfaced, indicating the superior efficacy of computer simulation-based instruction in Biology. Noteworthy mean disparities in post-achievement test scores further corroborated this finding, with treatment group students exhibiting a substantial improvement of 8.0 points more than their counterparts in the control group. These outcomes collectively underscore the enhanced performance and achievement witnessed among students instructed through computer simulation-based methodologies, positioning it as a more effective pedagogical approach for Biology education vis-à-vis traditional teaching methods.

Discussion

The study underscores the positive influence of both computer simulation and traditional teaching methods on Biology students' learning outcomes, encompassing achievement and memory retention. Through rigorous statistical analysis, the efficacy of these instructional approaches on students' post-achievement is substantiated. Notably, both the treatment and control groups exhibited notable improvements in their post-achievement test scores compared to their respective pre-test performances. These findings underscore the efficacy of both computer simulation and traditional teaching methods in enhancing students' comprehension, performance, achievement, and memory retention within the biology classroom.

However, a crucial distinction emerged upon further analysis, indicating a significant disparity in achievement and memory retention between students instructed via computer simulation and those taught through traditional methods. Notably, the cohort exposed to computer simulation demonstrated markedly higher scores in the post-achievement test relative to their counterparts educated through traditional pedagogical approaches. This highlights the superior efficacy of computer simulation in bolstering students' achievement and memory retention in the biology classroom compared to traditional teaching methods.

Comparison with existing literature

The findings of this study align with previous research conducted by Dikinson (n.d.), Chen (2002), and Stafford, Goodeough, and Davies (2010), which corroborate the efficacy of computer simulations in enhancing student learning outcomes. Of particular relevance is Dikinson's investigation into "the effect of computer simulated experiments on high school biology students' problem-solving skills" at Texas State University–San Marcos, which provides valuable insights into the benefits of utilizing computer simulations as a pedagogical tool in the field of biology. Dickinson's study highlights the superiority of computer simulations over traditional teaching methods in improving student learning outcomes.

Similarly, Jimoyiannis and Komis (2001) conducted a study contrasting students instructed in a typical classroom setting with those exposed to a combination of traditional teaching methods and computer simulations. Their research focused on the impact of this intervention on students' comprehension of fundamental kinematics concepts related to motion through Earth's gravitational field. Students who supplemented their conventional instruction with computer simulations exhibited notably higher performance on research tasks, suggesting the potential of computer simulations to enhance understanding of complex concepts such as acceleration and velocity. As such, the researchers advocate for the integration of computer simulations as a supplement or replacement for traditional teaching methods to facilitate deeper comprehension among students.

Implications of the study

The outcomes of this study yield a range of educational insights regarding the integration of computer simulations within secondary biology classrooms. Computer simulations offer dynamic and visually stimulating learning experiences that have the potential to enhance student motivation and engagement. The findings affirm that the incorporation of computer simulations aids in simplifying complex biological concepts. Furthermore, the study underscores that integrating simulations into the curriculum promotes critical thinking and the practical application of learned concepts.

Teachers are encouraged to adapt their pedagogical strategies to accommodate the diverse needs of students and foster an inclusive learning environment. Considering the evolving demands of both the workforce and higher education, educational institutions may find value in integrating these simulations into their curricula.

Limitations of the research

One limitation of this study is its reliance on a small sample size, consisting of only two secondary schools. Expanding the study to include a broader range of secondary schools could provide further insights. Additionally, exploring the impact of computer-based simulations on students' comprehension across various disciplines presents an intriguing avenue for future research.

Conclusion

While both traditional teaching methods and computer simulations offer benefits in biology education, this study suggests that computer simulations demonstrate superiority in facilitating learning outcomes. However, further investigation is warranted to explore the longitudinal effects of utilizing computer simulations in the teaching and learning process.

Recommendations for the future research

Future research endeavors should consider conducting longitudinal studies to assess the sustained impact of computer simulations on student learning. Moreover, employing a combination of quantitative and qualitative research methodologies can offer a comprehensive understanding of the teaching and learning dynamics associated with computer-based simulations.

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