Effects of Computer Simulation and Interactive Activities to Students' Academic Performance and Engagement in Cell and Molecular Biology

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Publication Date: 2025/10/30

Abstract: The study examined the effects of computer simulations and interactive activities on the academic performance and engagement of second-year Bachelor of Secondary Education Science students in Cell and Molecular Biology at Don Carlos Polytechnic College. A pretest-posttest research design was employed. Data were gathered using a 60-item validated researcher-made academic performance test in Cell and Molecular Biology and a 27-item engagement questionnaire. Findings were analyzed using mean, standard deviation, and ANCOVA. Findings revealed that computer simulations affect academic performance and promote student engagement across behavioral, affective, and cognitive domains. This enables students to achieve a reasonably satisfactory grasp with the ability to apply the essential knowledge acquired. A significant difference in academic performance was found between the computer simulation and interactive activity groups, indicating that the type of treatment had a substantial effect on learning outcomes. ANCOVA results for all engagement domains also indicated a significant effect of the treatment. Furthermore, students in the computer simulation group demonstrated more consistent responses across engagement domains, compared to those in the interactive activity.

Keywords: *Computer Simulation, Interactive Activities, Academic Performance, Engagement, Cell and Molecular Biology.*

How to Cite: Yvonne Catherine D. De Asis; Dr. Wilfred G. Alava Jr. (2025) Effects of Computer Simulation and Interactive Activities to Students' Academic Performance and Engagement in Cell and Molecular Biology.
International Journal of Innovative Science and Research Technology, 10(10), 1804-1819.
https://doi.org/10.38124/ijisrt/25oct1280

I. INTRODUCTION

Educators have increasingly adopted diverse strategies that encourage active participation and meaningful learning. Computer simulations and interactive activities have emerged as powerful tools for making science subjects more engaging and accessible. Simulations provide immersive environments where students can grasp complex concepts, receive immediate feedback, and retain knowledge more effectively. At the same time, interactive strategies such as the jigsaw method and role-playing promote collaboration, communication, and critical thinking by engaging students in realistic scenarios.

In the context of science education, the academic performance of students in cell and molecular biology is influenced by a network of factors that collectively affect their comprehension and engagement with the subject matter. Teaching and learning in the field of molecular and cellular biology are challenging, as evidenced by decades of empirical study on student learning and multiple national demands for instructional revision (Southard et al., 2016). Over the past decade, a growing body of research has supported the use of computer simulations to enhance science instruction. Olga et al. (2020) emphasized that simulations provide multisensory digital tools that support students' understanding of complex content and promote cognitive engagement by improving comprehension. According to Lee et al. (2021), the cognitive benefits and ease of use of simulations make them highly effective tools for instruction. Asmara et al. (2024) found that students who used the Jigsaw technique were more engaged, more motivated, and more likely to participate in class. These findings are consistent with previous research supporting cooperative learning as a way to improve participation and academic success in biology (Sharma et al., 2024). Similarly, role play has been effectively used in disciplines such as biology, anatomy, microbiology, nursing, and medicine (Church, 2021). tudent engagement is a vital aspect of teaching and learning, closely linked to student achievement. Engaged behavior includes attending school and classes,

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

following rules, completing class work, and maintaining a positive attitude toward subjects and education.

Globally, research has increasingly demonstrated the effectiveness of computer simulations and interactive strategies in improving science education. Numerous studies highlight how simulations simplify complex scientific concepts, foster deeper comprehension, and enhance retention through immersive and experiential learning (Olga et al., 2020; Lee et al., 2021). Likewise, interactive strategies such as the jigsaw method and role-playing have been shown to promote collaboration, motivation, and critical thinking (Asmara et al., 2024). However, while these tools are widely recognized as effective in general science teaching, there remains a global gap in their focused application to specialized fields like cell and molecular biology. Much of the international literature emphasizes broad STEM integration but provides limited evidence on how such tools can specifically address learning challenges in this highly abstract subject (Southard et al., 2016).

At the regional level, particularly in Southeast Asia, governments and educational institutions have pushed for the modernization of science instruction, placing emphasis on active and student-centered learning. Regional initiatives highlight the integration of digital tools and cooperative methods to improve comprehension and student participation in science classrooms. However, studies in the region often concentrate on general science or STEM education as a whole, rather than zooming in on cell and molecular biology. While regional findings point to the promise of innovative strategies like simulations and cooperative methods, there is still a gap in empirical studies that specifically examine their direct impact on comprehension and academic performance in this specialized domain.

Moreover, in the Philippine context, evidence shows that students continue to struggle with the demands of molecular and cellular biology, a subject that requires mastery of abstract and conceptually complex ideas. Although Filipino science instructors make use of multimedia tools such as PowerPoint presentations, videos, and interactive activities, many students still face significant challenges in comprehension and engagement.

Despite the growing body of research on the benefits of computer simulation in science education, there remains a gap in understanding its specific effect on student performance and engagement in cell and molecular biology. Additionally, while interactive strategies like jigsaw and role-playing have been shown to enhance learning in other contexts, these approaches, whether used individually or alongside computer simulations, have not yet been applied or studied at Don Carlos Polytechnic College. This presents an opportunity to examine their potential value in improving science education within the local context. Cell and Molecular Biology, in particular, is a challenging subject that often requires more than traditional textbook-based instruction. At Don Carlos Polytechnic College, science instructors frequently use multimedia tools such as PowerPoint presentations, videos, and interactive classroom activities to enhance learning. However, many students still struggle to comprehend complex and abstract biological topics. The use of computer simulations and interactive activities may support visual and experiential learning, potentially improving both academic performance and student engagement.

This study seeks to examine how the integration of computer simulations and interactive activities in Cell and Molecular Biology can improve students' academic performance and engagement. These approaches present innovative opportunities to address gaps in comprehension and learner participation by providing interactive, collaborative, and immersive learning experiences. In evaluating the effects of computer simulations and interactive activities, the study aims to offer insights into how such tools can be effectively implemented to enhance both academic performance and engagement, potentially contributing to long-term improvements in science education at Don Carlos Polytechnic College.

The study examines the effects of using computer simulations and interactive activities on students' academic performance and engagement in Cell and Molecular Biology. It was conducted at Don Carlos Polytechnic College during the school year 2024-2025.

➢ *Specifically, this Study Seeks to Answer the Following Questions:*

- What is the academic performance of students exposed to computer simulations compared to those exposed to interactive activities?
- What is the students' engagement exposed to computer simulations and those exposed to interactive activities, in terms of:

✓ Behavioral engagement;
✓ Affective engagement; and
✓ Cognitive engagement?

- Is there a significant difference in academic performance between students exposed to computer simulations and those exposed to interactive activities with pretest as covariate?
- Is there a significant difference in students' engagement between students exposed to computer simulations and those exposed to interactive activities with pretest as covariate?

II. LITERATURE REVIEW

➢ *Academic Performance and Computer Simulation*

Simulations have been shown to enhance learning and increase engagement, thereby facilitating the faster assimilation of scientific concepts by students (Manunure et al., 2019). In recent years, many innovative educational solutions have emerged to improve teaching and learning processes. Among these, computer simulations have proven to be effective instructional tools and are now included in science education (Langbeheim & Levy, 2019). These simulations are designed to create scenario-based

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

environments where students can actively engage with content and apply their prior knowledge and practical skills to real-world problems, thereby promoting in-depth learning (Vlachopoulos & Makri, 2017).

Computer simulations enhance students' comprehension of challenging and abstract concepts, significantly improving academic performance and retention especially in the instruction of complex subjects (Cheung et al., 2016). Adebayo and Oladele (2016) emphasized that computer simulation is a valuable instructional approach for teaching and mastering complex topics. Their findings suggest that students taught using computer simulation achieve higher conceptual understanding compared to those taught through traditional lecture methods.

Olorukooba et al. (2016) similarly found that students taught using computer simulations outperformed those taught using conventional lecture methods. This perspective is further supported by Lasisi et al. (2021), who highlighted the advantages of integrating simulations to enhance academic performance. Numerous studies have validated the positive effect of computer simulations on students' academic performance and retention, particularly in the field of genetics. Akhigbe and Ogufere (2019) also found that students taught using a non-traditional method, including simulations, demonstrated better academic performance and developed more favorable attitudes toward genetics compared to those taught through traditional methods.

Further studies demonstrate the effectiveness of simulations in explaining intricate biological concepts such as DNA replication and transcription. For instance, Olalekan and Oludipe (2016) reported that students taught using computer simulations scored significantly higher on posttests than those who received traditional lecture-based instruction. Similarly, Chinenye et al. (2019) found that computer simulations were more effective than demonstration approach for teaching biology, particularly in topics related to cells and their environment by enhancing students' ability to visualize and comprehend complex concepts. A meta-analysis by Talan (2021) concluded that simulation-based instruction significantly improves academic performance. Similarly, the study of Nkemakolam O. et al. (2018) demonstrates that the use of computer simulations in educational settings enhances students' academic performance. Students taught using computer simulations performed significantly better in physics compared to those taught using conventional methods (Cezar, 2024). Despite differences in participant characteristics across studies, the consistent use of computer simulations has yielded similar positive results in instructional effectiveness and learning gains.

Cano et al. (2021) developed simulation-based instructional materials to teach the Central Dogma of Molecular Biology and found that these resources enhanced student engagement and comprehension of abstract scientific concepts. Likewise, Teke, Dogan, and Duran (2015) confirmed that students taught through computer simulations exhibit improved academic performance.

➢ *Engagement and Computer Simulation*

Student engagement refers to emotional, behavioral, and cognitive investment in the learning process, which directly influence their academic success and achievement (Almasri et al., (2021). A study conducted by Eun and Young (2017) on cooperative learning activities utilizing simulations revealed that such simulations help students gain firsthand knowledge by examining topics from multiple perspectives, hence improving their academic performance, communication skills, and final grades. She et al. (2019) in their analysis of the PISA 2015 evaluation, examined students' capabilities to engage in scientific inquiry via computer-based simulations. Their findings suggest that students' epistemic beliefs and motivation significantly influence their participation in scientific tasks, indicating that fostering positive attitudes toward science can enhance behavioral engagement. Similarly, research by Isiaq and Jamil (2017) shows that simulator-based sessions effectively enhance behavioral and emotional engagement in students.

Lindgren et al. (2016) defined "student engagement" as the involvement of students in both cognitive and perceptual experiences during simulation-based literacy activities. Simulation-based learning not only enhances participants' cognitive understanding of the subjects matter but also boosts their motivation and overall engagement. The degree to which students invest time and effort in engaging with the learning process is referred to as their level of engagement (Almasri, 2022). Furthermore. Lee et al. (2021) suggested that computer simulations can enhance students' cognitive and emotional literacy, leading to increased learning satisfaction and sustained engagement. Supporting these findings, Cezar (2024) reported that students exposed to computer simulations demonstrated significantly higher levels of engagement across behavioral, affective, and cognitive domains compared to those taught through traditional instructional methods.

➢ *Academic Performance and Interactive Activities*

In contrast to traditional methods of teaching, the implementation of interactive teaching strategies, such as the jigsaw method, has been shown to significantly improve learning outcomes (Rajan et al., 2023). Collaborative approaches like the jigsaw approach, are crucial for developing students' academic skills, problem-solving abilities, and communication proficiency. In contrast to traditional approaches, the jigsaw method stands out as a novel technique that actively engages students and promotes profound comprehension of concepts, as noted by Dnyanesh et al. (2022). Winslow (2020) further suggests that the Jigsaw approach, enhances academic performance, boosts self-esteem, and fosters more positive attitudes toward learning. Similarly, Sharma et al. (2024) found that the jigsaw approach has positively effect academic achievement by increasing both comprehension and student engagement.

Juweto (2015) emphasized that the jigsaw method demonstrated greater effectiveness compared to traditional teaching methods, underscoring its potential as a transformative instructional strategy in science education. Sharma et al. (2024) noted that the jigsaw approach improves academic performance by reducing cognitive load through

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

collaborative efforts. Students often encounter increased cognitive demands when engaging with challenging subjects, such as biology (Drouet et al., 2023). The jigsaw technique helps ease cognitive burden associated with complex subjects by promoting collaboration (Sharma et al., 2024). Additionally, Klau (2023) reported that the jigsaw approach has a positive effects academic performance, peer interaction, and learning engagement.

Chen et al. (2021) conducted an experimental study that compared role-playing with traditional teaching methods. The role-playing teaching method was found to improve students' test scores and enhance students ' skills in case studies. Role-play has been recognized as one of the most effective techniques for developing competencies such as initiative, self-awareness, problem-solving, communication, and teamwork (Kaovere & Mbaukua, 2018). The utilization of role-play as a pedagogical strategy demonstrates efficacy in achieving learning outcomes across three primary domains: affective, cognitive, and behavioral (Sangeetha, 2017). In addition, the study demonstrated that the application of the Jigsaw approach led to substantial increase in the percentage of students achieving excellent grades, along with notable reduction in the number of students receiving low grades (Myrzagaliyeva et al., 2024).

➢ *Engagement and Interactive Activities*

Role-playing is an interactive educational method in which students engage in relevant scenarios to develop cognitive, affective, and behavioral understanding. They may portray imaginary characters or, in some cases, represent themselves A separate study revealed that the Jigsaw method enhanced both behavioral and academic performance in biology education. Students taught with the Jigsaw method not only achieved higher scores but also demonstrated increased interest and engagement compared to their peers in conventional lecture-based environments (Ojekwu & Ogunleye, 2020). The Jigsaw model was combined with role-playing to enhance speaking skills. The intervention resulted in a significant improvement in student engagement and speaking performance, with success rates increasing from 62.5% to 90% across two consecutive cycles.

A study examining student responses to the incorporation of Jigsaw and Role-Playing in physics revealed that participants valued the collaborative learning framework and believed it enhanced their understanding of abstract concepts. The Jigsaw method elicited a generally positive response from students, while the combination enhanced engagement among a variety of students (Astalini et al., 2021). Numerous studies have examined the learning benefits of employing role-play in the classroom, either in combination with or as an alternative to other instructional methods, highlighting increased student engagement and interest (Stevens, 2015). Role-play is a strategy in which students are required to act in specific roles through saying, doing, and sharing (Altun, 2015).

The role-playing method serves as a teaching approach that simulates real-life situations. The simulation of real-life situations occurs when students assume specific roles, guided by the teacher who presents the scenario (Bajis et al., 2021). Educators continue to investigate this method due to it is highly engaging nature, which allowing participants' deeper involvement and increases enjoyment in the learning process. Abdullah (2017) provides a clear discussion of the benefits and drawbacks of the jigsaw learning model and role-playing. He notes that the advantages of both methods include enhanced student motivation, fostering mutual respect among peers, creating opportunities for open expression of ideas due to the small group sizes, and developing practical communication skills in students. The jigsaw technique, in particular, has demonstrated significant effectiveness in improving student learning and engagement across various subjects and educational levels. Research indicates enhancements in mastery, learning activities, learning outcomes, and critical thinking dispositions (Yuhananik, 2018).

Moreover, the Jigsaw technique has been shown to positively influence student engagement in various educational settings. Asmara et al. (2024) found that students who participated in the jigsaw learning were more engaged in class activities, contributed actively to discussions, and reported higher motivation to learn. This approach serves as a valuable strategy for creating a more engaging and motivating learning environment.

Role-playing has been applied across various disciplines, including biology, anatomy and physiology, microbiology, nursing, and medicine often yielding favorable educational outcomes (Church, 2021). Local research also validates the value of simulation in the Philippine setting. Cano et al. (2021) found that simulation-based instructional materials for Grade 12 biology significantly improved mastery of the Central Dogma, shifting learners from "approaching proficiency" to "advanced mastery."

Furthermore, the study of Salubayba, Serrano, Baconguis, and Dicolen (2018) likewise showed that the Jigsaw technique enhanced understanding of cellular structure among Grade 7 students in Laguna, producing higher gains compared to traditional teaching. Similarly, De Torres et al. (2024) revealed that interactive simulation significantly improved the science performance of Grade 8 students in Occidental Mindoro. In medical education, Yelton et al. (2022) implemented a Manila-based simulation curriculum on pediatric shock, which enhanced confidence and simulation performance despite limited resources. These studies highlight that simulations and interactive methods, even within the Philippine context, effectively foster engagement and academic improvement across various disciplines.

Both Jigsaw and role-playing techniques share common goal of enhancing student collaboration and engagement, yet they function through different mechanisms. Jigsaw method emphasizes peer teaching and content mastery while role-playing focuses on experiential learning and skill application. The findings from Theobald et al. (2017) support the notion that perceptions of group dynamics significantly influence individual performance, indicating that both methods can be

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

effective when appropriately implemented and contextually aligned.

III. METHODOLOGY

The study employed a pretest-posttest research design, utilizing two intact classes as participants. Data were collected through academic performance tests and student engagement questionnaires to assess the effects of the intervention. One intact class was assigned to the computer simulation, while the other intact class was assigned to the interactive activities. Both classes completed a pre-test to determine the initial equivalence prior to intervention. Subsequently, lessons were conducted for both intact classes, each following the 7E's lesson plan format to ensure instructional consistency. The pretest-posttest design helps control for pre-existing differences between the groups. A post-test on academic performance was administered after the implementation of the different interventions. Following data collection, the results were analyzed and interpreted.

The study was conducted at Don Carlos Polytechnic College. A local college run by the Local Government Unit (LGU) of the Municipality of Don Carlos, Bukidnon. The school offers programs for a Bachelor of Elementary Education, Bachelor of Science in Criminology, and Bachelor of Secondary Education major in English, Mathematics, Filipino, and Science. The focus of the study was on the Bachelor of Secondary Education major in Science, the curriculum includes courses in biology, one of which is Cell and Molecular Biology. This course served as a foundational subject that introduced students to the structure and function of cells, biomolecules, and cellular processes, which were essential for understanding advanced biological concepts.The school is recognized for its best educational practices, continuously producing topnotchers in licensure examinations. Remarkably, it ranked in the Top 5 for the Bachelor of Secondary Education (BSED) in 2017 and the Top 6 for the Bachelor of Elementary Education (BEED) in 2022.

The participants in the study consisted of two intact classes of second-year Bachelor of Secondary Education (BSED) Science students, aged 19–21 years old, enrolled in Bio102 (Cell and Molecular Biology) at Don Carlos Polytechnic College during the first semester of the 2024–2025 academic year. The two intact classes in the study consisted of 60 students: 30 in the computer simulation group and 30 in the interactive activities group. The sample size was determined based on the total enrollment in the course during the first semester. This course was a required part of the curriculum for second-year BSED science students during the term, making this group representative of the entire population of interest. The study intends to collect data using computer simulations and interactive activities. However, it is also acknowledged that some students may have access to personal computers or other devices. To overcome this, the study only included students who were using suitable technologies. There were other options, such as allowing students who did not have their laptops or gadgets to use shared school resources. Additionally, data collection was mobile-friendly, enabling students with smartphones to participate in part.

Development of 7Es Lesson Plan Integrating Computer Simulation and Interactive Activities.

➢ *Design and Development*

This section discussed how computer simulations and interactive activities are used to actively engage students in the complex processes of molecular biology during the Engage to Explore phase of the lesson. The lesson plan is anchored on the 7Es instructional model, guiding students through each concept using interactive methods and assessments.

- *Need Analysis.*

The needs analysis survey was conducted among teachers. They were asked to identify specific challenging lessons in Cell and Molecular Biology that could be enhanced through the use of computer simulations and interactive activities. With the topics and strategies identified, the researcher prepared two separate Task Analysis Matrices (TAMs) for computer simulation and interactive activities as a guide for organizing the lesson, which include the following components: objectives, science concepts, learning outcomes, and assessments used. The lessons were taken from the course syllabus of the Cell and Molecular Biology course, typically covered during the final term. The sequential arrangement of DNA replication, transcription, and translation ensured logical progression and continuity throughout the learning process.

- *Writing the Lesssons*

This phase involved designing two lessons that incorporated computer simulations and interactive activities, focusing on the key genetic processes in molecular biology. The following components were integrated using the 7Es model:

- *Elicit*:

In the computer simulation and interactive activity, students engaged in a brainstorming session, decoding message activity, and think-pair-share in all the lessons. The teacher guided the discussion, summarized student responses, and organized ideas on the board to prepare for the next lesson.

- *Engage*:

The teacher showed a short animation showing DNA replication, transcription, and translation. Then, students engaged with a computer simulation that allowed them to manipulate and observe the simulation. Following this, students answered questions about the simulation.

The teacher started with the same animation; thereafter, instead of engaging with a screen, students performed designated roles such as DNA strands, enzymes, and RNA molecules in a mini role-play, actively enacting the processes of replication, transcription, and translation. The activity concluded with a brief review and peer discussion.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

- *Explore:*

The students were divided into four groups and examined DNA replication, transcription, and translation through computer simulation. As they engaged with the simulation, the groups interacted directly with virtual representations of key enzymes. They manipulated and observed effects and carefully completed a worksheet that required them to identify each enzyme and explain its function based on their observations within the simulation.

Simultaneously, another group of students engaged in a jigsaw learning activity. Initially, within their assigned groups, each member became an "expert" on a particular DNA replication, transcription, and translation enzyme, examining given illustrations and explanations to understand its specific function fully. Then, these "experts" regrouped into a newly formed group. In this context, they took turns teaching one another about their assigned enzymes, collectively establishing a thorough comprehension of the DNA replication, transcription, and translation enzymes through collaborative learning.

- *Explain:*

Following the activity, the groups prepared brief presentations. They presented their findings to the class, explaining the changes they observed in the simulation as well as the relationships between the enzymes.

After the interactive discussions, students presented their findings, using visual aids such as diagrams to explain the enzyme to the class. The information they provided explained how the enzyme works, its function, and its role in the process of DNA replication, transcription, and translation, and it enhanced the knowledge established before the prior activity.

- *Elaborate*:

Using computer simulations, the class was divided by the teacher into six collaborative groups, each tasked with determining the sequence of DNA replication, transcription, and translation. Students referred back to the simulation as needed, carefully arranging the stages into a well-structured flowchart.

The class was subsequently reorganized into smaller groups, with each group assigned to enact or role-play the processes of DNA replication, transcription, and translation. Following the performance, each group provided a concise explanation of their role play to describe the concepts portrayed.

- *Evaluate:*

The lesson concluded with a short quiz administered to both the computer simulation and interactive activities. Students were able to reinforce the ideas they had learned throughout the lesson by showing their understanding of the processes and functions involved in DNA replication, transcription, and translation.

- *Extend*:

After the evaluation, students from both the computer simulation and the interactive activity engaged in a series of extension tasks, which included conducting inquiry-based research, comparing and contrasting activities, and creating comprehensive infographics.

The study utilized a researcher-made test to assess academic performance, while an adapted questionnaire was utilized to evaluate student engagement.

The academic performance of students exposed to computer simulations and interactive activities was measured using a scale and data interpretation. A 100-item multiple-choice academic performance test was administered to 50 third-year BSED Science students to establish its reliability and test its internal consistency. The reliability testing obtained a Cronbach's alpha of 0.998, indicating excellent internal consistency for the measurement tool. This suggests that the items within the scale are strongly correlated and likely measure the same underlying construct. Based on this analysis, only 60 items were accepted for the study. The 60-item test covered three topics in Cell and Molecular Biology: DNA replication, DNA transcription, and DNA translation. The following outlines the scoring procedure used to interpret the students' academic performance data, with percentage equivalents based on the grading system of Don Carlos Polytechnic College (DCPC-BOT Resolution No. 09, Series of 2011).

For engagement, the 27-item Students' Engagement Questionnaire by Nazamud-din et al. (2020) has three components: Behavioral Engagement, Affective Engagement, and Cognitive Engagement. The students responded based on the given statements. The engagement scale was modified to fit the subject. Each engagement scale was rated using the 5-point Likert Scale. Based on the result of Cronbach's alpha, which is 0.983, indicates excellent reliability or internal consistency among the items in the questionnaire under behavior, affective, and cognitive engagement.

The data in the study were treated carefully to ensure that the results were accurate and valid. The following statistical tools were used in data analysis. The mean and standard deviation were used to assess the students' academic performance and level of engagement. The Analysis of Covariance (ANCOVA) was employed to compare post-test scores between the two groups, with pre-test scores included as a covariate to control for initial differences. The significance level was set at 0.05, and the null hypotheses for both academic performance and engagement were tested.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

IV. PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

Table 1 Academic Performance of Students as Exposed to Computer Simulation and Interactive Activities

Raw Scores	**Qualitative Description**	**Computer Simulation**				**Interactive Activities**			
		Pre-test		***Post-test***		***Pre-test***		***Post-test***	
		f	%	*f*	%	*f*	%	*f*	%
58-60	Excellent	0	0	0	0	0	0	0	0
51-57	Very Good	0	0	0	0	0	0	0	0
45-50	Good	0	0	3	10	0	0	0	0
42-44	Average	0	0	4	13.3	0	0	1	3.3
38-41	Fair	0	0	13	43.3	0	0	13	43.3
34-37	Poor	0	0	9	30	0	0	12	40
30-33	Passing	1	3.3	1	3.3	1	3.3	4	13.3
29 and below	Failed	29	9.7	0	0	29	9.7	0	0
Mean		22.76		39.26		23.60		36.76	
SD		3.01		3.74		4.18		3.31	
Qualitative Description		Failed		Fair		Failed		Poor	

Legend: f - Frequency, % - Percent/Percentage

As shown in the pre-test results, the majority of students were classified at the Failed level in both intervention groups, with only one learner achieving a *Passing* level in each of the computer simulation and interactive activities groups. The results indicate that students in the Computer Simulation group showed a significant improvement in their post-test scores. Most students moved from the *Failed* category to the *Fair* and *Good* categories, as evidenced by the increase in the post-test mean score of 39.26 and a standard deviation of 3.74. On the other hand, students in the Interactive Activities showed progress, though are considerable portion remained in the lower performance. The mean score of 36.76 and standard deviation of 3.31 are comparatively lower than those of the Computer Simulation.

The findings suggest that computer simulations yielded more significant results, indicating Fair that students' understanding of DNA replication, transcription, and translation is reasonably satisfactory or passably good, and that they are capable of applying the essential knowledge acquired and likely because they were better able to visualize these intricate processes. The increase in standard deviation in the computer simulation indicates that, while most students improved, some students improved significantly more than others.

In contrast, interactive activities also improved, but the progress was less pronounced. The decrease in standard deviation suggests more equal progress among students. The results are similar and evenly delivered in nature, but also indicate fewer improvements. This indicates that the student meets the requirement but shows only slight comprehension of the subject matter such as the DNA replication, transcription, and translation and needs further development, though the performance is fairly acceptable to proceed to the next course in sequence. Although interactive activities foster retention by reinforcing ideas through social interaction, they may not provide the same level of individualized visualization that computer simulations offer.

The results above strongly support previous research on simulation-based learning. Studies have consistently shown that computer simulations enhance learning by improving engagement, conceptual understanding, and retention of complex topics (Manunure et al., 2019; Langbeheim & Levy, 2019; Vlachopoulos & Makri, 2017). Moreover, Adebayo and Oladele (2016) emphasized that computer simulation simplifies complex concepts, leading to improved academic achievement. This finding is corroborated by studies from Olorukooba et al. (2016), Lasisi et al. (2021), and Asogwa et al. (2016), which all reported improved student performance in science subjects when simulations were used. Furthermore, computer simulations are effective in teaching intricate biological processes, such as DNA replication, transcription, and cellular functions (Olalekan & Oludipe, 2016; Chinenye et al., 2019). In addition, Lindgren et al. (2016) and Almasri (2022) argue that simulations encourage not only higher engagement but also greater investment in the learning process due to their capacity to align cognitive challenges with active participation. Additionally, the comparative results from the interactive activities support other research. Strategies such as the jigsaw method promote collaborative learning and are effective in enhancing academic achievement, communication skills, and problem-solving abilities (Rajan et al., 2023; Winslow, 2020; Sharma et al., 2024). While they may not always match the performance gains seen in simulations, interactive methods reduce cognitive load and foster deeper engagement through peer interaction (Drouet et al., 2023; Klau, 2023).

Table 2 Students' Behavioral Engagement as Exposed to Computer Simulation and Interactive Activities

Indicators	**Computer Simulation**						**Interactive Activities**					
	Pre-test			***Post-test***			***Pre-test***			***Post-test***		
	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD
I review the completed task on molecular biology problems before submitting it to my instructor	3.83	0.79	HE	4.50	0.51	VHE	3.66	0.76	HE	3.26	1.60	HE

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

Indicators	Computer Simulation						Interactive Activities					
	Pre-test			***Post-test***			***Pre-test***			***Post-test***		
I watch cell and molecular biology videos suggested by my instructor.	4.23	0.82	VHE	4.56	0.50	VHE	3.88	0.83	HE	4.03	0.72	HE
I identify key information from cell and molecular biology reading assignments.	3.70	0.65	HE	4.50	0.51	VHE	3.66	0.76	HE	4.10	0.76	HE
I attend the class before molecular biology sessions start	3.80	0.76	HE	4.56	0.50	VHE	3.76	0.81	HE	4.20	0.81	HE
I always complete the task given by the instructor in class during lessons.	4.00	1.08	HE	4.60	0.50	VHE	4.06	0.78	HE	4.36	0.67	VHE
I regularly participate in class discussions on cell and molecular biology class.	4.20	0.92	HE	4.66	0.48	VHE	4.00	0.83	HE	4.40	0.67	VHE
I often discuss with my friends what I'm learning in cell and molecular biology class.	3.70	1.06	HE	4.50	0.51	VHE	3.83	0.79	HE	4.16	0.79	HE
I ask my instructor questions during molecular biology class if I do not understand.	3.86	0.97	HE	4.53	0.51	VHE	3.70	0.75	HE	4.00	0.69	HE
I take advantage of available learning resources other than what my instructor has provided.	3.66	0.96	HE	4.55	0.48	VHE	3.63	0.81	HE	4.53	0.68	VHE
MEAN	**3.88**	**0.84**	**HE**	**4.55**	**0.48**	**VHE**	**3.79**	**0.75**	**HE**	**4.11**	**0.67**	**HE**

Legend: VHE= Very High Engagement; HE=High Engagement; ME= Moderate Engagement; LE= Low Engagement; VLE= Very Low Engagement

Interval Range	Response	Qualifying Statement
4.21–5.00	Strongly Agree	Very High Engagement
3.41–4.20	Agree	High Engagement
2.61–3.40	Neutral	Moderate Engagement
1.81–2.60	Disagree	Low Engagement
1.00–1.80	Strongly Disagree	Very Low Engagement

The table lists several behavioral indicators and compares pre-test and post-test results using mean scores and standard deviation. The computer simulation demonstrated an improvement in behavioral engagement, with mean scores increasing from 3.88 in the pre-test to 4.55 in the post-test. Students progressed from High Engagement to Very High Engagement across all indicators. The decrease in standard deviation, from 0.84 to 0.28, suggests that students not only improved in general but also did consistently. Additionally, this suggests that simulation helped students to be more equally behaviorally engaged. Otherwise, the interactive activities also experienced an increase in some indicators, but the changes were more minor and less consistent. The post-test standard deviation in this group slightly decreased from 0.75 to 0.67.

The findings suggest that computer simulation is more effective in promoting greater consistency in behavioral engagement. The visual and interactive nature of simulations likely contributed to gaining attention, increasing engagement with content, following instructions, and promoting more active participation among different types of students in the classroom. On the other hand, interactive activities can improve behavior engagement; they appear to be more varied and may depend on the learner's preferences or group. This might explain why some indicators did not show substantial or consistent improvement in the interactive group.

These results are consistent with earlier research that links simulation-based learning to higher behavioral engagement. Eun and Young (2017) reported that cooperative simulations enhance academic performance, communication skills, and engagement by helping students explore multiple perspectives. She et al. (2019) concluded that computer-based simulations promote active scientific inquiry, especially when students hold positive beliefs about science and feel behaviorally motivated. Another study by Almasri et al. (2021) emphasized that behavioral engagement is tied to students' investment in the learning process, which simulations actively support through their dynamic, visual, and interactive environments. Furthermore, Isiaq and Jamil (2017) found that simulations significantly enhance both behavioral and emotional engagement, indicating their broad effect across different learning domains. Simulations also enhance cognitive and affective engagement, both of which contribute to behavioral responses.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

Table 3 Students' Affective Engagement as Exposed to Computer Simulation and Interactive Activities

Indicators	Computer Simulation						Interactive Activities					
	Pre-test			***Post-test***			***Pre-test***			***Post-test***		
	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD
I feel energized by the ideas I am learning in cell and molecular biology.	4.26	0.69	VHE	4.70	0.47	VHE	3.83	0.75	HE	3.33	1.52	HE
I feel that the course is challenging, but hard work in molecular biology can help me succeed	4.43	0.63	VHE	4.96	0.18	HE	4.03	0.72	HE	4.10	0.71	HE
I feel that interaction with my classmates helps me understand molecular mechanisms better:	4.46	0.82	VHE	4.56	0.50	HE	4.10	0.76	HE	4.06	0.78	HE
I feel excited about the activities that we experience in the classroom.	4.36	0.72	VHE	4.66	0.50	HE	3.86	0.78	HE	3.93	0.83	HE
I realize that I have learned something that changed the way I understand a concept.	4.26	0.74	VHE	4.93	0.25	HE	3.76	0.73	HE	4.13	0.68	HE
I feel as though I am learning things in molecular biology that are worthwhile to me as a person.	3.86	0.73	HE	4.86	0.35	HE	3.86	0.97	HE	4.10	0.71	HE
In the last week, I've been bored in molecular biology class a lot of the time	3.40	1.07	ME	3.30	1.21	ME	2.40	0.89	LE	2.43	1.33	LE
I feel fascinated about the cell and molecular biology content	3.73	0.98	HE	4.60	0.50	HE	3.80	0.81	HE	3.83	0.87	HE
I feel that I am an important member of my learning team.	3.86	0.82	HE	4.50	0.51	HE	3.73	0.78	HE	4.60	0.62	VHE
MEAN	**4.07**	**0.74**	**HE**	**4.56**	**0.18**	**HE**	**3.71**	**0.75**	**HE**	**3.83**	**0.64**	**HE**

Legend: VHE= Very High Engagement; HE=High Engagement; ME= Moderate Engagement; LE= Low Engagement; VLE= Very Low Engagement

Interval Range	Response	Qualifying Statement
4.21–5.00	Strongly Agree	Very High Engagement
3.41–4.20	Agree	High Engagement
2.61–3.40	Neutral	Moderate Engagement
1.81–2.60	Disagree	Low Engagement
1.00–1.80	Strongly Disagree	Very Low Engagement

The results revealed that the use of computer simulations led to a significant improvement in student engagement levels. The mean score increased from 4.07 in the pre-test to 4.56 in the post-test. Students progressed from High Engagement to Very High Engagement, reflecting a notable enhancement in students' participation, focus, and enthusiasm toward learning Cell and Molecular Biology.

The reduction in standard deviation from 0.74 to 0.18 indicates greater consistency in responses, suggesting that most students benefited uniformly from the intervention. This demonstrates that computer simulations not only heightened engagement but also reduced disparities in learner involvement. The interactive, visual, and experiential nature of simulations likely enabled students to understand abstract concepts more effectively, thereby sustaining interest and motivation.

In contrast, the interactive activities also resulted in improved engagement, though to a lesser extent. The mean score increased from 3.71 in the pre-test to 3.83 in the post-test. Students consistently demonstrated High Engagement, indicating that students responded positively to collaborative learning strategies such as role-playing and the jigsaw method. However, the standard deviations remained relatively high, suggesting variability in student responses and differing levels of active participation. This implies that while interactive activities successfully encouraged communication, teamwork, and critical thinking, not all learners were equally engaged possibly due to factors such as group dynamics, confidence levels, or individual learning preferences. Despite this variability, interactive activities still maintained a high level of engagement and contributed meaningfully to students' participation and motivation.

The findings support the assertion that computer simulations are effective at strengthening affective engagement by creating dynamic learning environments. Almasri (2022) explains that simulations can enhance emotional and cognitive literacy, contributing to more satisfying learning experiences. Likewise, Lee et al. (2021) found that students using simulations expressed stronger emotional responses and a deeper interest in the subject, likely due to the medium's visual, self-paced, and exploratory nature. Noskova et al. (2021) emphasize that digital learning an environment rich in multimedia, video, and interactivity is more likely to stimulate positive emotions and increase learner engagement.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

Table 4 Students' Cognitive Engagement as Exposed to Computer Simulation and Interactive Activities

Indicators	**Computer Simulation**						**Interactive Activities**					
	Pre-test			***Post-test***			***Pre-test***			***Post-test***		
	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD
It is hard to pay attention in my cell and molecular biology class.	2.63	1.13	ME	3.83	1.21	HE	2.10	0.80	LE	1.56	0.68	VLE
I form a new understanding from various concepts in my cell and molecular biology class.	3.83	0.65	HE	4.50	0.41	VHE	3.70	0.88	HE	3.83	0.75	HE
I can usually find ways of applying what I'm learning in cell and molecular biology class to something else in my life.	3.96	0.67	HE	4.46	0.51	VHE	3.60	0.67	HE	3.93	0.83	HE
I examine the weakness of my own views on molecular biology concepts.	3.96	0.81	HE	4.43	0.50	VHE	3.73	0.74	HE	3.80	0.76	HE
I find myself thinking about what I'm learning in cell and molecular biology class even when I'm not in class.	3.63	0.72	HE	4.53	0.63	VHE	3.46	0.78	HE	3.86	0.73	HE
I evaluate the opinion discussed in the classroom.	3.86	0.86	HE	4.46	0.62	VHE	3.40	0.62	HE	3.96	0.72	HE
I examine the strength of my own views on molecular biology concepts	3.90	0.71	HE	4.00	0.74	HE	3.76	0.63	HE	4.06	0.83	HE
I memorize important course notes after the lecture.	3.80	0.61	HE	4.16	0.53	HE	3.90	0.71	HE	3.86	0.73	HE
I summarize what I have learned in cell and molecular biology class.	4.00	0.74	HE	4.16	0.46	HE	3.76	0.73	HE	4.56	0.68	VHE
MEAN	**3.73**	**0.72**	**HE**	**4.31**	**0.40**	**VHE**	**3.49**	**0.66**	**HE**	**3.71**	**0.64**	**HE**

Legend: VHE= Very High Engagement; HE=High Engagement; ME= Moderate Engagement; LE= Low Engagement; VLE= Very Low Engagement

Interval Range	**Response**	**Qualifying Statement**
4.21–5.00	Strongly Agree	Very High Engagement
3.41–4.20	Agree	High Engagement
2.61–3.40	Neutral	Moderate Engagement
1.81–2.60	Disagree	Low Engagement

The findings reveal that students exposed to computer simulations obtained greater improvement in academic performance, as evidenced by an increase in their mean scores from 3.73 in the pre-test to 4.31 in the post-test. The results indicate that students progressed from High Engagement to Very High Engagement, suggesting heightened cognitive engagement among students. Those exposed to simulations demonstrated better focus, conceptual understanding, and use of cognitive strategies. In contrast, students who participated in interactive activities obtained a smaller improvement, with mean scores rising from 3.49 in the pre-test to 3.71 in the post-test. Students constantly showed High Engagement. Likewise, participants in interactive activities exhibited notable gains, showing even greater improvement than those in the simulation group. Additionally, the standard deviation for computer simulations decreased from 0.74 to 0.40. showing more consistent engagement levels across students. In contrast, interactive activities showed relatively neutral pre-test and post-test scores, remaining in the Engaged. Overall, the results suggest that both computer simulations and interactive activities effectively enhanced and stabilized students' cognitive engagement.

This result is consistent with other study findings; for instance, Kew and Tasir (2021) found that simulations increase focus and motivation, helping students go beyond surface learning to develop deeper comprehension. Lindgren et al. (2016) noted that simulation-based environments support students' perceptual and mental engagement with content, improving both understanding and retention. Furthermore, Almasri (2022) and Lee et al. (2021) reported that simulation tools help students organize information more effectively and apply it across contexts, fostering not only retention but also transfer of knowledge.

Table 5 Summary of Students' Engagement Exposed to Computer Simulation and Interactive Activities

Indicators	**Computer Simulation**						**Interactive Activities**					
	Pre-test			***Post-test***			***Pre-test***			***Post-test***		
	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD	x̄	SD	QD
Behavioral	3.88	0.83	HE	4.55	0.48	VHE	3.79	0.75	HE	4.11	0.67	HE
Affective	4.07	0.74	HE	4.56	0.18	VHE	3.71	0.75	HE	3.83	0.63	HE
Cognitive	3.73	0.71	HE	4.31	0.40	VHE	3.49	0.66	HE	3.71	0.64	HE

Legend: VHE= Very High Engagement; HE=High Engagement; ME= Moderate Engagement; LE= Low Engagement; VLE= Very Low Engagement

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

Interval Range	Response	Qualifying Statement
4.21–5.00	Strongly Agree	Very High Engagement
3.41–4.20	Agree	High Engagement
2.61–3.40	Neutral	Moderate Engagement
1.81–2.60	Disagree	Low Engagement

As shown in the computer simulation, the pre-test mean scores for Behavioral, Affective, and Cognitive engagement were all within the High Engagement. In the post-test, the means increased significantly, indicating a shift to the Very High Engagement. Examining the mean values, computer simulation, and interactive activities showed improvements in all three engagement dimensions. In particular, students in both groups showed higher average engagement scores in behavioral, affective, and cognitive dimensions. The standard deviation decreased after the interventions across most indicators.

The increase in mean scores across all engagement dimensions indicates that computer simulation and interactive activities were effective in students' engagement. The results suggest that, after implementation, both measures indicate that students were more attentive, emotionally invested, and cognitively involved in their learning. It also indicates that students' engagement scores became more similar to each other and showed less variation within each group.

These findings align with extensive research that defines student engagement as the combined influence of behavioral participation, emotional connection, and cognitive effort (Almasri et al., 2021). Sinatra et al. (2015) describe it as being attentive, persistent, and cooperative in learning contexts. Studies by She et al. (2019) and Isiaq and Jamil (2017) demonstrate that computer simulations increase active participation, particularly in science education, by fostering favorable attitudes and motivation toward inquiry-based tasks. Affective engagement reflects students' interest, enthusiasm, and emotional involvement. Alrashidi et al. (2016). Pohl (2020) and Edwards et al. (2020) assert that students who are cognitively engaged are more likely to achieve academic success. Lindgren et al. (2016) and Lee et al. (2021) confirm that simulation-based learning supports deeper comprehension, critical thinking, and sustained motivation—characteristics reflected in the increased cognitive engagement in the simulation group.

Table 6 Summary of Students' Engagement Exposed to Computer Simulation and Interactive Activities

Source of Variance	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Squared
Academic Performance Pre-test	16.643	1	16.643	1.434	.236	.025
Treatment	109.786	1	109.789	9.457*	.003	.142
Error	661.690	57	11.609			

*Significant at Alpha < .05,
Cohen's Guidelines on Eta Squared
(0.2 – Small Effect, 0.5 – Moderate Effect, 0.8 – Large Effect).

The results indicate that computer simulation and interactive activities show a statistically significant effect on academic performance. The p-values in the table indicate the probability that the observed effects occurred by chance. In this analysis, the p-value associated with the treatment was below the accepted level of significance ($p < 0.05$). This means there is strong evidence to conclude that the type of instructional strategy has a real effect on students' academic performance rather than the observed differences being due to random variation. In contrast, the p-value related to the pre-test was above the significance level, indicating that initial differences in students' academic performance did not significantly influence the post-test academic performance in the study. Furthermore, the Partial Eta Squared of .025 indicates that the pre-test accounts for only 2.5% of the variance in academic performance, suggesting a small effect. In contrast, the Partial Eta Squared of .142 indicates that the treatment accounts for 14.2% of the variance in academic performance, representing a small to moderate effect. This reinforces the conclusion that the instructional strategies, computer simulation and interactive activities, had a statistically significant impact on improving students' academic performance.

This suggests that the observed improvements in academic performance are primarily the result of the computer simulation and interactive activities rather than the students' initial pre-test scores. As a result, the null hypothesis that there is no significant difference in academic performance in Cell and Molecular Biology between second-year students exposed to computer simulations and those exposed to interactive activities is rejected, suggesting that the instructional strategy used had a meaningful effect on students' post-test scores. The results presented above are consistent with the findings of previous studies, such as those by Adebayo and Oladele (2016) and Olorukooba et al. (2016). The improved performance of students exposed to computer simulations in this study reflects the ability of such tools to simplify complex biological concepts and enhance achievement beyond traditional lecture methods. Similarly, findings by Asogwa et al. (2016) and Akhigbe and Ogufere (2019) support the notion that simulation-based instruction fosters better comprehension and retention of challenging topics, particularly in genetics and molecular biology.

Moreover, the advantages of interactive learning strategies, such as the jigsaw method, are corroborated by studies (Rajan et al., 2023; Dnyanesh et al., 2022; Winslow,

2020) that document improvements in academic skills, engagement, and collaborative problem-solving through active student participation. The present findings reflect the effectiveness of these cooperative methods in facilitating a more profound understanding and learner-centered environments, as highlighted by Sharma et al. (2024) and Klau (2023).

Table 7 Comparison of Engagement Between Computer Simulation and Interactive Activities

Source of Variance	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p-value**	**Partial Eta Squared**
Behavioral Engagement Pre-test	9.965	1	9.965	58.257*	.000	.505
Treatment	2.215	1	2.215	12.950*	.001	.185
Error	9.749	57	0.171			-
Affective Engagement Pre-test	6.274	1	6.274	55.502*	.000	.505
Treatment	4.575	1	4.575	40.468*	.000	.185
Error	6.444	57	0.113			
Cognitive Engagement Pre-test	6.509	1	6.509	37.207*	.000	.395
Treatment	3.398	1	3.398	19.425*	.000	.254
Error	9.972	57	0.175			

*Significant at Alpha < .05,
Cohen's Guidelines on Eta Squared
(0.2 – Small Effect, 0.5 – Moderate Effect, 0.8 – Large Effect).

For each type of engagement, the table shows the effects of pre-test scores and the treatment. The p-values for both pre-test and treatment effects across all engagements are reported. For the pre-test, the p-values are below the accepted level of significance ($p < 0.05$), indicating a highly significant effect of students' initial engagement levels on their post-test engagement. For the treatment, the p-values are 0.001 or lower for all engagement types, indicating that the p-value is below the accepted level of significance, which shows that the difference between computer simulation and interactive activities in influencing engagement is statistically significant. Furthermore, the Partial Eta Squared of .505 indicates that the pre-test behavioral engagement accounts for 50.5% of the variance in post-test behavioral engagement. The treatment accounts for 18.5% of the variance with a Partial Eta Squared of .185. For affective engagement, the Partial Eta Squared values of .505 and .185 indicate that pre-test and treatment explain 50.5% and 18.5% of the variance, respectively. For cognitive engagement, the Partial Eta Squared of .395 for pre-test accounts for 39.5% of the variance, while the treatment effect size of .254 accounts for 25.4% of the variance. Thus,these Partial Eta Squared values represent large effects. The results show that students' initial engagement levels strongly influenced their post-test engagement. Moreover, the instructional interventions using computer simulations and interactive activities significantly improved students' behavioral, affective, and cognitive engagement.

Moreover, the p-values for the treatment effect across behavioral, affective, and cognitive engagement confirm that the choice between computer simulation and interactive activities made a real, non-random difference in how engaged students became. This statistical significance indicates that the observed improvements in engagement are highly unlikely to be due to chance. As a result, the null hypothesis that there is no significant difference in the level of learner engagement between those exposed to computer simulations and those exposed to interactive activities is rejected, supporting the idea that simulations and interactive activities are practical tools for enhancing various dimensions of student engagement.

The finding aligns with the broader understanding of student engagement as a measurable, multidimensional construct (Almasri et al., 2021), where differences in instructional approach produce distinct effects on how students participate, feel, and think during learning. The statistically significant difference in behavioral engagement supports earlier findings by She et al. (2019) and Isiaq and Jamil (2017), who reported that computer-based simulations lead to higher levels of active participation in scientific inquiry. The significance of the treatment effect here confirms that simulation sessions offer a more structured and engaging environment, helping students stay focused and involved.

Another study, supported by Alrashidi et al. (2016), emphasizes the effect of positive emotions on learning. The significance of treatment effects in this domain echoes the results from Pohl (2020), Edwards et al. (2020), and Lindgren et al. (2016), who found that simulations improve deep learning, critical thinking, and cognitive persistence. Although simulations were found to have a more substantial statistical effect overall, interactive activities are still effective in enhancing engagement. Research by Ojekwu and Ogunleye (2020) and Astalini et al. (2021) supports the idea that peer collaboration can significantly raise interest and participation, particularly among socially motivated students. However, both strategies are more context-dependent, often influenced by group dynamics, learner personality, and communication skills (Theobald et al., 2017). This variability may explain the statistical differences found between the two instructional strategies, with simulations offering more consistent engagement outcomes across diverse learner profiles.

V. SUMMARY AND FINDINGS

➢ *Summary*

The study examined the effect of computer simulations and interactive activities on the academic performance and engagement of second-year Bachelor of Secondary Education (BSED) Science students enrolled in Bio102 (Cell and Molecular Biology) at Don Carlos Polytechnic College during the first semester of the academic year 2024–2025. There

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25oct1280

were 30 students who were exposed to computer simulation, while another 30 students participated in interactive activities, both conducted within the framework of the 7E instructional model. The results indicated that the use of computer simulations significantly influenced both academic performance and learner engagement.

Additionally, the researcher employed the mean, standard deviation, and One-way Analysis of Covariance (ANCOVA) at a 0.05 level of significance to assess the significant difference in academic performance test results in Cell and Molecular Biology between the Interactive Activities and Computer Simulation groups.

➢ *Findings*

The study yielded the following significant findings:

- Students who participated in computer simulations achieved a Fair level of academic performance in Cell and Molecular Biology, whereas those who engaged in interactive activities performed Poorly in performance level.
- The students exposed to computer simulation showed Very High Engagement in all engagement levels, Behavioral, affective, and cognitive engagement, compared with the students exposed to interactive activities, who had High Engagement in all engagement levels.
- The results indicate that the treatment, computer simulation, and interactive activities show a statistically significant effect on academic performance. This suggests that the observed improvements in academic performance are primarily resulting from the computer simulation and interactive activities as opposed to the students' initial pretest scores.
- There is a significant difference in the students ' engagement between those exposed to computer simulation and those exposed to interactive activities. The p-values are below the accepted level of significance, showing that the difference between computer simulation and interactive activities in influencing engagement is statistically significant.

VI. CONCLUSION

➢ *The Findings of the Study Led to the Following Conclusions:*

- Computer simulations affect academic performance in Cell and Molecular Biology. It is a more effective instructional tool for supporting learner understanding and academic performance and enabling students to achieve a reasonably satisfactory grasp of the subject matter, with the ability to apply the essential knowledge acquired
- Computer simulations appear to be very high engagement, which promotes higher levels of student engagement across behavioral, affective, and cognitive domains. This suggests that simulations not only support learning but also enhance motivation, attention, and active participation in the learning process.
- The improvements in academic performance can be attributed to the use of computer simulation and interactive activities rather than to students' initial pretest scores. This highlights the effect of these instructional strategies in enhancing students ' academic performance.
- The significant difference in learner engagement between the computer simulation and interactive activities has a measurable effect on student engagement.

RECOMMENDATION

➢ *Based on the Conclusions Drawn from the Study, the Following Recommendations are Proposed:*

- It is recommended that computer simulations be regularly integrated into the teaching of not only cell and molecular biology but also other complex subjects. Utilizing such tools may enhance students' comprehension of difficult concepts and promote greater engagement.
- Include computer simulations in lessons to keep students interested and motivated and may examine how simulations effect different subjects and other program courses.
- Combine computer simulations with other interactive activities, such as group work or role-playing, to enhance students' learning effectiveness. Future research may examine which combinations of interactive strategies work best for various lessons.
- Provide training for teachers on the effective use of computer simulations and other interactive teaching methods to enhance student learning outcomes.
- Consider other educational technologies such as augmented reality, virtual laboratory, or educational games alongside computer simulations. Assessing their comparative effectiveness may provide insights into which tools are most suitable for enhancing learning in specific subject matter.

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