The Impact of Collaborative Learning Strategies on 9th-grade Biology Students' Learning Outcomes

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Abstract

This research investigated how collaborative e-learning strategies affected the understanding of DNA Replication among the 9th-grade Biology CC class. The study involved 24 diverse students (ages 15-17), including regular education students, English Language Learners (ELLs), and students with IEPs selected through proportional stratified random sampling. Using a mixed-methods approach, the research measured learning outcomes through pre- and post-tests and gathered data on student learning experience through an end-of-lesson survey. Students engaged with digital tools for collaborative learning activities, including Quizizz, Canvas, DNA simulator, and Canva Whiteboard. Data analysis combined the Wilcoxon Signed-Rank Test for quantitative data and thematic analysis for qualitative responses. Results showed a substantial improvement in student performance, with mean scores increasing from 50% to 91%. While students reported high engagement and satisfaction with collaborative learning, time management and appropriate spacing of learning activities emerged as key challenges. Future research would benefit from implementing a control group and extending the timeline to accommodate all students and IEP requirements better.

Keywords: digital tools, DNA replication, e-learning, high school teaching, student evaluation

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Chapter 1: Introduction

Instructional Problem

The learners in my 9th-grade Biology CC class at Wisdom High School (*pseudonym*) in Las Vegas, Nevada, are composed of regular students and those with Individualized Education Programs (IEPs). Students currently face significant challenges in understanding DNA Replication. While they grasp basic scientific concepts, they struggle to understand the complex mechanisms involved in this biological process. The primary instructional problem is bridging the gap between simple fact-finding and deeper conceptual understanding or knowledge construction. Many students can identify what happens during the S phase of the Cell Cycle, but have difficulty explaining how this process happens or why it is essential. The lack of interactive, engaging, and hands-on learning experiences critically undermines students' knowledge-construction abilities, creating a significant barrier to a deeper understanding of DNA Replication.

Research Topic

The topic of this design-based research explores how collaborative learning strategies (discussion boards, digital whiteboard collaborations, and peer feedback) impact the learning outcomes and experiences of my 9th-grade biology students. This investigates how technology supports the learning of "DNA Replication" by actively engaging with the content and promoting student-to-student interaction instead of just reading texts by themselves. This research explores learning outcomes and the development of interpersonal skills such as teamwork, problem-solving, and conflict management.

The study of DNA Replication is not only interesting but a crucial part of our state's educational standards, specifically the Nevada Academic Content Standards for Science (NVACSS) under the standard: "HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells" (CCSD, 2024). By understanding this process, students gain insights into both the microscopic world of molecular biology and the larger picture of how living things function and thrive.

Collaboration is an important aspect of effective learning that benefits students. When learners work together, they can see problems and concepts from different perspectives, which deepens their understanding of the subject matter. By explaining ideas to classmates and engaging in group discussions, students reinforce their knowledge and discover new approaches to solving problems. Working collaboratively also develops essential real-world skills that are valuable beyond the classroom. Students learn how to communicate effectively, develop leadership abilities, and respect different opinions – all crucial skills for future careers and personal growth.

Research Questions

The main objective of this research is to assess how learning strategies impact the learning outcomes and experiences of 9^{th}-grade students at Wisdom High School.

Specifically, this study aims to answer the following questions:

1. How does the use of collaborative strategies in an e-learning module impact understanding of DNA Replication as measured by the pre- and post-test?
2. What are the perceptions of my students in using digital collaborative tools as measured by an attitude survey?

Research Purpose

This research study aims to examine the impact of an e-learning module on students' understanding of DNA Replication and to measure their perceptions or attitudes toward using digital collaborative tools. By understanding how collaborative activities influence student learning and experiences, I can tailor instructional strategies to create a more engaging, dynamic, and responsive learning environment.

Chapter 2: Literature Review

Introduction to the Literature Review

Recent academic researchers have shown significant interest in collaborative learning methodologies, especially in the field of science education (Gaad, 2022; Bass et al., 2024; Li & Liang, 2024). This pedagogical approach, which emphasizes student-centered engagement and collective knowledge construction, has exhibited potential for improving outcomes across various academic disciplines and educational levels. This literature review examines how collaborative strategies in an e-learning module, specifically in biology, affect the learning outcomes of 9th-grade students at Wisdom High School. This systematic analysis examines how collaborative learning is used in science education, affects student performance and engagement, and helps students develop 21st-century skills.

Theoretical Foundation of Collaborative Learning in Education

Collaborative learning is based on social constructivist theory, which believes knowledge is constructed through social interaction (Vygotsky, 1978). According to Vygotsky's sociocultural theory of child development, social interactions fundamentally mediate cognitive development. This theoretical framework suggests that learning is inherently collaborative, as knowledge construction occurs within social contexts. In teaching biological concepts, this approach is consistent with the nature of scientific inquiry, which often involves teamwork and peer review (Goldsmith et al., 2024). Johnson and Johnson (2009) found that when students collaborate, they engage in higher-order thinking and develop critical reasoning skills for grasping complicated biological topics.

Implementing Collaborative Learning Strategies in Teaching Biology

Research has shown the effectiveness of various collaborative learning approaches in teaching biology. Jigsaw strategies, in which students become experts on a topic and subsequently teach their peers, have been especially helpful in improving understanding of biological systems (Aronson & Patnoe, 2011). Problem-based learning (PBL), in which small groups work on real-world biological problems, has also improved content retention and application (Hmelo-Silver, 2004). Collaborative whiteboards in biology classrooms are digital platforms that enable students to collaborate in real-time on shared visual spaces. Students can simultaneously contribute to the whiteboard, creating a more engaging and dynamic learning environment (Sun et al., 2017). According to Taylor (2012), more than 80% of learning and development practitioners believe collaborative learning is effective. However, data shows that only 20% consistently use collaborative learning as an instructional strategy.

Impact on Learning Outcomes and Academic Achievement

Findings from several studies show that the implementation of effective collaborative strategies enhances learning outcomes (Lane & Tegtmeyer, 2020; Kozan et al., 2023; Oyarzun & Martin, 2023). A comprehensive meta-analysis by Kyndt et al. (2013) reveals a positive effect of collaborative learning on achievement and attitudes. Similarly, Etokeren et al. (2019) found that students who participated in collaborative learning activities performed much better on tests than those who attended standard lecture-based sessions in high school biology. However, while collaborative strategies can enhance learning, not all students thrive in group settings (Hung, 2019; Glaister et al., 2024).

Student Engagement and Motivation in Collaborative Learning

Collaborative learning has been found to improve student engagement and motivation in biology classes. According to the study of Hampden-Thompson and Bennett (2013), empirical evidence suggests that students who participated in collaborative activities expressed greater interest and satisfaction in biology than those who attended standard courses. Furthermore, Gillies and Boyle's (2010) research substantiates that collaborative learning fosters collective responsibility and enhances students' willingness to contribute to group-based projects. Despite the cited advantages, Torres (2020) pointed out several challenges in collaborative learning environments. These impediments include generating and articulating ideas, interpersonal dynamics, insufficient participation from disengaged group members, and a lack of communication.

Development of 21st-Century Skills through Collaborative Learning

Over the past decade, educators have recognized the importance of integrating 21st-century pedagogical strategies and technology in education. Hagler (2024) stated that "teachers have developed diverse methodologies to help students develop essential skills for the 21st century across various age groups. Collaborative learning in biology improves content mastery and develops scientific competencies and dispositions. Osborne's (2010) research presented that collaboration in science classes increases students' abilities to create hypotheses, design experiments, and interpret data. Likewise, Tanner (2013) discovered that collaborative learning promoted positive attitudes toward biology and boosted students' self-efficacy in scientific inquiry. Collaborative learning in biology education has been linked to developing crucial 21st-century skills. Studies by Ramdani et al. (2022) have shown that collaborative learning environments promote communication skills, adaptability, and digital literacy among biology students. Moreover, research by Scager et al. (2016) demonstrated that collaborative projects in 9th-grade biology classes enhanced students' creativity and innovation skills.

Conclusion

Based on the reviewed literature, there is compelling evidence that collaborative learning strategies significantly enhance learning outcomes for biology students. The research consistently demonstrates improvements across multiple areas: academic performance, student engagement, and developing essential skills in 21st-century education when collaborative approaches are implemented effectively. However, it is important to note that the success of these strategies often depends on factors such as proper implementation, teacher preparation, and the specific context of the learning environment. Future research could focus on the long-term effects of collaborative learning in biology education and its impact on students' career choices.

I closely consider ways to develop a practical e-learning module incorporating collaborative learning strategies. The research findings, particularly the high success rate of collaborative learning in biology education demonstrated by Etokeren et al. (2019), indicate that developing a solution based on collaborative principles would be advantageous. However, the considerable gap between perceived effectiveness (80%) and actual implementation (20%) suggests that this learning strategy must carefully address the obstacles to wider acceptance.

As I design the e-learning module, I should integrate digital tools, such as collaborative whiteboards (Sun et al., 2017), while supporting the accommodation of different learning styles. Structured collaboration should be implemented through proven strategies like Jigsaw discussion, with clear guidelines for group interaction to address the challenges that Torres (2020) identified regarding participation and communication. Importantly, acknowledging Hung's (2019) and Glaister et al.'s (2024) findings that not all students thrive in group settings, the modules should include options for individual work within the collaborative framework. The design should also incorporate elements that develop scientific competencies (Osborne, 2010) and promote 21st-century skills such as communication, adaptability, and digital literacy, as Ramdani et al. (2022) emphasized. Furthermore, the e-learning module should include mechanisms to track individual contributions and group progress and assessment tools that measure content mastery and skill development. This comprehensive approach suggests that an effective e-learning module should balance structured collaboration and individual learning opportunities while leveraging digital tools to enhance engagement and facilitate skill development, including support systems (accommodations) to address the common challenges identified in the literature review.

Chapter 3: Research Methodology

Instructional Problem Overview

The primary instructional problem I identified involves adapting modern teaching methods and technology in my 9th-grade Biology class at Wisdom High School. The class includes students with different learning needs, including those with IEPs and English Language Learners (ELLs). Each student is provided a Chromebook for them to use for their classwork, and their seats are already arranged in groups. While they have basic science knowledge and can use computers, they need support in understanding complex biology topics like "DNA Replication" as part of the State standards. Though students talk and socialize, they need to improve their teamwork skills to better show mastery and understanding of the lesson.

Potential Solutions

To solve these challenges, I plan to create an e-learning module that uses interactive tools, simulation, and group activities. This approach will help meet different learning needs and deliver the standards while teaching important 21st-century skills that will help students succeed in school and their future careers. The instructional presentation will be delivered by online module with multimodal content resources available in English and Spanish. A gamified pre-test, interactive simulations, discussion, and collaborative whiteboard will facilitate the learning activities. The assessments will be administered using a progress tracker, reflection, post-test, peer feedback, and infographic.

Kahoot!

Kahoot! could serve as an effective collaborative learning tool. The platform could be implemented to support the diverse learners in my biology class by creating a team-based Kahoot! (Team Mode) challenges where students work together in small groups to discuss and select answers instead of competing individually. The collaborative aspect could be enhanced by incorporating discussion periods between questions, where teams must explain their reasoning to each other before submitting answers.

One advantage of implementing Kahoot! is its ability to facilitate immediate, real-time feedback in an engaging format. Its instant feedback mechanism allows me to immediately identify areas where my students are struggling collectively, enabling me to adjust my teaching strategies on the spot and address misconceptions before they become embedded in them.

I anticipate that one of my biggest challenges will be ensuring equitable participation among my diverse learners. Since my classroom includes students with IEPs, I need to be mindful of how to make the app accessible and engaging for everyone. To address this challenge, I plan to implement several strategic supports. First, I will create carefully balanced mixed-ability teams, ensuring that students who are more advanced in their understanding can support those who may have gaps in their foundational knowledge. I will let students choose or assign specific roles within each team to guarantee that every student has a meaningful way to contribute, whether it's as the answer submitter, discussion leader, or fact-checker. Then, I will incorporate scaffolding strategies such as reviewing or pre-teaching essential vocabulary and concepts before we begin our Kahoot! session. Also, I can design the question sets with varying difficulty levels and include visual supports when appropriate.

Canva Whiteboard

I could also use Canva's Whiteboard to provide a dynamic student engagement and knowledge construction space. I would create collaborative workspaces, embed the access link to their Canvas page, and let them use the Canvas Whiteboard to map out the process of DNA Replication as groups. This concept mapping activity is where students can illustrate their understanding of the lesson while peers add questions or clarifications using different colors to track comprehension levels and participation.

One significant advantage of using Canva Whiteboard is its ability to facilitate real-time visual knowledge construction. When teaching topics like DNA Replication, the whiteboard's collaborative feature allows my students to collectively build and refine their understanding by simultaneously adding, editing, and organizing visual elements.

Since it indicates that students currently have only "basic computer operation" skills as part of their current KSAs, some learners might struggle with navigating the digital whiteboard interface, potentially leading to frustration or disengagement from collaborative activities. To address this, I will include step-by-step instruction or video in both English and Spanish, develop a simple digital skills checklist for self-assessment (progress tracker), and carefully scaffold - beginning with simple activities to build confidence before gradually introducing more complex features.

Nearpod

Another option is to design an interactive lesson through Nearpod. For teaching complex concepts like DNA Replication, I would utilize Nearpod's collaborative features, such as “Time to Climb” for vocabulary building and the “Collaborate Board.” The “Draw It” feature would allow students to create and label collectively. I could also incorporate Nearpod's interactive polling and discussion features to make the lesson more engaging.

One advantage of implementing Nearpod is its ability to provide real-time formative assessment while maintaining active participation from all students. Its interactive features allow me to instantly assess student understanding through various engaging activities while ensuring that both regular students and those with IEPs can participate equally. For example, when teaching DNA Replication, I can use quick checks for understanding that provide immediate feedback, allowing me to adjust my instruction on the spot.

One challenge I can think of in implementing Nearpod would be managing consistent internet connectivity and device access for all students. Though the school issues Chromebooks, not all students bring theirs, or sometimes they don’t bring it fully charged. Unreliable internet access could disrupt the collaborative learning experiences and widen the gap between current and desired KSAs rather than bridge them. To address this challenge effectively, I would create offline alternatives for all Nearpod activities, ensuring that students can seamlessly transition between online and offline modes without disrupting their learning experience. Alternatively, establish a buddy system where students who have reliable access can partner with those who might experience connectivity issues, supporting the document's emphasis on structured collaboration.

I believe using Canva Whiteboard effectively bridges the Knowledge, Skills, and Abilities (KSA) gap in e-learning modules through collaborative learning. It directly addresses these gaps through its user-friendly interface and comprehensive collaborative features. It supports visual learning and knowledge construction and lets students demonstrate an understanding of DNA Replication by creating an infographic.

Canva Whiteboard is a better choice than Kahoot and Nearpod due to its alignment with the research goals, emphasizing the need for "knowledge construction" and "structured collaboration" rather than just fact-finding. While Nearpod and Kahoot excel at quick assessments and engagement, Canva Whiteboard better aligns with the document's desired KSAs by enabling deeper collaborative learning experiences. Unlike Kahoot's gamified multiple-choice format or Nearpod's guided presentation style, Canva Whiteboard allows students to visually map out the complex stages of DNA Replication collaboratively. Students can create detailed visual representations of the Interphase and M phase, add annotations, and work together to demonstrate their understanding of the whole process. While Nearpod and Kahoot offer limited collaboration through synchronized responses or team games, Canva Whiteboard provides real-time, multi-user collaboration where students can simultaneously work on different parts of DNA Replication, provide peer feedback, and create comprehensive visual models. Furthermore, it offers advantages through guided meaning-making and integration of both English and Spanish text or explanations, and this flexibility better serves the diverse classroom population.

E-Learning Unit of Instruction Description

Table 1

Description of the Designed E-Learning Module

Module Title	***DNA Replication***
Module Description	In this lesson, students will investigate how chromosome differences happen in cancer cells. They are going to share their initial ideas about chromosomes and then use a computer simulation and reading to find answers to questions. In the previous lesson, they learned that chromosomes duplicate through DNA replication during the S phase. During this process, mutations can occur, which can cause differences in the DNA and chromosomes. p53 can correct those mutations, but not all versions of p53 do that work. They will construct an infographic, give and receive peer feedback, and revise their explanations.
Target Audience	9th-grade biology students of Wisdom High School
Learning Goal	This lesson aims for the students to develop a deeper understanding of biological systems and be able to construct an explanation based on evidence about how mutations can occur during DNA replication, resulting in differences in chromosomes, and the role of p53 in their repair. This goal encourages students to explore biological processes while building critical thinking and analytical skills, which aligns with student grade-level Nevada Academic Content Standards for Science (NVACSS): • HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells.
Learning Objectives	By the end of the lesson, students should be able to... 1. Write initial ideas about DNA and chromosomes.

	2. Explain the role of p53 in repairing errors in a DNA sequence. 3. Create an infographic showing how DNA replication and mutation can happen.
Assessments	***Formative:*** • Canva Whiteboard – Students will post or share initial ideas about DNA and chromosomes • Computer simulation – They will explore DNA replication, how mutation happens, and how p53 repair errors • Discussion board – Students will construct explanations and give peer feedback on the explanation ***Summative:*** • DNA Replication Model/Infographic – With a small group, students will create an infographic explaining DNA replication, how mutation happens, and how p53 repair error in a DNA sequence • Quiz - a 15-item test to check student understanding of the lesson
Learner Needs	***Language Support and Communication Challenges*** I anticipate that students may struggle to understand the content and instructions in the e-learning platform if they're only in one language. Also, during collaborative online activities language barriers might limit participation in groups, affect peer quality feedback, and impact knowledge construction activities. To address this challenge, I will use a Learning Management System (LMS) capable of translating texts, provide bilingual reading materials, enable closed captioning in

	both languages when watching instructional videos, and design collaborative groups with language consideration. ***Varied Academic Levels*** Students might need differentiated instructions, especially those with IEPs to accommodate their needs. When implementing the e-learning module, students will have different completion rate, varying levels of engagement, and different abilities to use technology. To support my students, I can include supplementary resources for struggling students, design flexible assessment options, scaffold instruction, and use structured approaches when collaborating to create an infographic.
Learning Technology	***Nearpod*** • Nearpod has a robust language support features that is appropriate for a bilingual learning environment. It also offers text translation capabilities, audio support, visual aids, and multilingual instructions. This ensures that both English and Spanish-speaking students can fully engage with the learning materials and participate effectively in class activities. • It can help support differentiated learning by providing, self-paced learning options, and diverse content formats including videos, slides, and activities. • This e-learning tool has features that can make learning more interactive and engaging, helping students understand content. I can monitoring students’ progress through real-time assessment data and provide intervention opportunities, if needed.

	Canva Whiteboard • Canva Whiteboard has intuitive interface, easy-to-use tools, zoom capabilities for detailed work, and multiple ways to represent information ensure that all students can participate effectively in infographic construction activities. • This e-learning tool is appropriate for structured collaboration and knowledge construction. Students can work together in real-time, making simultaneous edits and seeing their peers' contributions instantly. • It also provides an array of tools that help students construct an infographic. Students can use drag-and-drop elements, drawing tools for scientific diagrams, shapes and connectors for concept mapping, and text boxes for labeling and explanations.
E-Learning Module	Overall, this e-learning module effectively addresses the diverse needs of bilingual students, special needs learners, and tech-savvy social learners through its thoughtful integration of technology and collaborative approaches. The use of Nearpod's robust language support features, including text translation capabilities, audio support, and multilingual instructions, ensures that bilingual students can fully engage with the content in both English and Spanish. For special needs students, the module offers differentiated instruction through flexible assessment options and scaffolded learning approaches, while the self-paced learning options accommodate different completion rates and abilities. Tech-savvy students who enjoy socializing will particularly benefit from the interactive activity of using the Canva Whiteboard, as these platforms enable real-time collaboration, instant peer

	feedback, and creative expression through digital tools. The collaborative infographic project specifically caters to social learners by allowing them to work in small groups, make simultaneous edits, and see their peers' contributions instantly. Additionally, the structured discussion boards and peer feedback activities provide multiple opportunities for meaningful social interaction while maintaining academic focus on understanding DNA replication, mutations, and the role of p53.

Research Methodology

Method

This study will utilize both quantitative and qualitative methods for data collection and analysis. To answer the research question, “How does the use of collaborative strategies in an e-learning module impact understanding of DNA Replication as measured by the pre- and post-assessment?” the Wilcoxon Signed-Rank Test will be used to determine if there’s a statistically significant difference between the student’s scores. Data from students' perceptions or attitudes about digital collaborative tools in class through an end-of-lesson survey will be analyzed using a Likert scale and thematic analysis. It will answer, “What are the perceptions of my students in using digital collaborative tools as measured by an attitude survey?”

Participants/Stakeholders

The study will involve 24 students from my 9th-grade Biology CC classes at Wisdom High School in Las Vegas, Nevada. The class population ranges in age from 15 to 17 years old and includes regular education students, English Language Learners (ELLs), and those with Individualized Education Programs (IEPs). There will be 4 participants for each class period, and they will be selected through random proportional stratified sampling to ensure representative participation across student groups. Using a research randomizer tool, I will use student ability grouping as a stratified variable and draw a sample.

The results of the study could provide valuable insights to the school’s Special Education Case Managers in supporting diverse learners. It could provide information on how to better accommodate students with special needs in science instruction. The differentiated instruction provided in the e-learning module could also provide alternative ways for students with different learning styles to engage with complex content. Moreover, the focus on constructing explanations based on evidence reflects exam expectations, which could potentially benefit Testing Coordinators. The study is aligned with Nevada Academic Content Standards (NVACSS HS-LS1-1). The collaborative approaches studied reflect the skills tested in the end-of-course Criterion-Reference Test (CRT) in Biology, such as critical thinking, scientific explanation, and evidence-based reasoning.

Data Collection Instrument(s)

Test Scores

The pre-test and post-test scores analysis provide quantitative evidence of student's understanding of the lesson and the impact of the e-learning module. The pre-test will be given through a Quizizz game with multiple-choice questions. The pre-test will establish students' initial understanding of DNA Replication, identify existing knowledge gaps and misconceptions, and provide a starting point for measuring growth. At the end of the lesson, students will take a 15-item objective-type quiz in Canvas that assesses their understanding of the content. Post-test scores will be compared directly to pre-test scores, and the differences between scores will indicate knowledge gained and improvement of concept mastery through the implemented e-learning module. This assessment aligns with the research purpose by providing concrete data on the effectiveness of the collaborative learning strategies.

Student Attitude Survey

An end-of-lesson survey will be administered through a Google Form. The survey includes Likert scales, multiple choice, and short-answer questions that aim to measure student perceptions and attitudes toward digital collaborative tools. This student attitude survey can evaluate student motivation, engagement levels with lesson activities, challenges encountered, and student suggestions. This comprehensive survey approach helps fulfill the research purpose of this study in examining the impact of an e-learning module and understanding how collaborative activities influence student learning experiences.

Data Analysis Technique(s)

Test Scores

The Wilcoxon Signed-Rank Test is a non-parametric statistical test that evaluates whether there's a significant difference between students' pre-test and post-test scores after experiencing my designed collaborative e-learning module. The test begins by calculating the difference between each student's paired scores ($D_i = Post_i - Pre_i$). These differences are then ranked by their absolute values, excluding any zeros (where pre- and post-scores were identical). The original signs (positive or negative) are reattached to these ranks, indicating whether performance improved or declined. The test statistic (W) is calculated from these signed ranks and compared to critical values to determine statistical significance.

For this study, the null hypothesis would state that there's no significant difference between pre- and post-test scores, while the alternative hypothesis would suggest that the collaborative strategies in the e-learning module created a significant impact on student understanding of DNA Replication. Using a typical significance level of $\alpha=0.05$, the null hypothesis will be rejected if the resulting p-value is less than 0.05, indicating that the collaborative learning strategies significantly impacted student understanding. This test is appropriate for this research because it doesn't require the assumption of normal distribution, works well with smaller class sizes, and accounts for both the direction and magnitude of changes in student performance. The results will provide quantitative evidence to support or challenge the effectiveness of the collaborative learning strategies in improving students' understanding of DNA Replication and will be presented through bar graphs.

Student Attitude Survey

Quantitatively, the Likert scale would systematically quantify students' attitudes and perceptions through a series of structured response options. A 5-point scale will be used, where 1= Not at all engaged, 2= Not Engaged, 3=Neutral, 4= Engaged, and 5=Very Engaged. This numerical coding allows for statistical analysis of otherwise qualitative perceptions. The survey would assess multiple dimensions of the collaborative learning experience of the e-learning module, including attitudes toward discussion boards, digital whiteboard collaborations, and peer feedback systems. Questions, including the multiple select, would evaluate students' comfort levels with the technology, perceived effectiveness or challenges of collaborative activities, and their assessment of how these tools supported their understanding of DNA Replication.

Qualitatively, the survey includes two (2) short-answer questions that ask student's suggestions for improvement. These open-ended questions would allow students to express their e-learning experience freely. The responses would gather detailed feedback about their learning experiences, challenges encountered, and suggestions for enhancing the collaborative learning environment. It will be analyzed through thematic analysis and will be presented through network maps. According to Nowell et al. (2017), to establish the trustworthiness of the thematic analysis, the following process must be followed:

1. Familiarizing yourself with data
2. Generating initial codes
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

Expected Timeline

The instructional time at Wisdom High School consists of 82 minutes per class period. The e-learning module implementation will require two consecutive class periods within the block schedule format. Data collection procedures will be conducted over a five-day period from April 7 through April 10, 2025.

Data Security and Confidentiality

As I conduct this research with my 9th-grade Biology students at Wisdom High School, I can maintain strict data security and confidentiality standards by creating a coding system to replace my students' names with anonymous identifiers throughout my data collection and analysis. I will store all my data securely using password-protected devices, keeping physical documents in locked cabinets and digital files backed up in secure, institution-approved cloud storage platforms. I will strictly control access to my research data, limiting it only to essential team members, and I'll maintain careful access logs. Throughout my study, I will maintain detailed documentation of all my security procedures, including any potential data breaches or concerns.

Conclusion

In my study, I will be using both quantitative and qualitative methods to understand how collaborative strategies in my e-learning module affect student learning. There will be 24 participants from my 9th-grade Biology CC students at Wisdom High School in Las Vegas, ranging from 15 to 17 years old. My class is quite diverse, including regular education students, English Language Learners (ELLs), and students with IEPs. Four (4) participants from each class period will be selected using random proportional stratified sampling to ensure I have a representative sample across all student groups.

For the data collection, two main instruments will be used. First, I will measure student understanding through pre- and post-tests. I will start with a Quizizz game as my pre-test, in which by the end of the lesson, students will take a 15-item objective quiz in Canvas as post-test with 2 allowable attempts. This will help me see how much my students' understanding of DNA Replication has improved. Additionally, I will let students fill out an end-of-lesson survey through Google Forms to gather my students' thoughts and experiences with the digital collaborative tools.

When analyzing data, I will use the Wilcoxon Signed-Rank Test to determine if there's a significant difference between my students' pre and post-test scores. I have chosen this test because it works well with my small class size and doesn't require normal distribution. I will analyze the Likert scale data (using a 5-point scale) and multiple select answers for the survey responses and conduct a thematic analysis of the open-ended responses.

I plan to implement this study from April 7 through April 10, 2025, during my 82-minute class periods. My research aligns with Nevada Academic Content Standards and could provide valuable insights for our Special Education Case Managers and Testing Coordinators. I am particularly interested in how my collaborative approaches can support diverse learners and improve their understanding of complex scientific concepts.

Chapter 4: Results

Summary of Research

This research was conducted at Wisdom High School in Las Vegas, Nevada, focusing on how collaborative learning strategies impact understanding the DNA Replication of the designed module in 9th-grade Biology CC classes. Furthermore, this study aims to answer the following questions: "How does the use of collaborative strategies in an e-learning module impact understanding of DNA Replication as measured by the pre- and post-assessment?" and "What are the perceptions of my students in using digital collaborative tools as measured by an attitude survey?"

Participants were selected through random proportional stratified sampling, with four students chosen from each class period to ensure representative participation across student groups. The study involved 24 students aged 15-17, including regular education students, English Language Learners (ELLs), and students with Individualized Education Programs (IEPs). The intervention utilized an e-learning module featuring a computer simulation, discussion boards, and a Canva Whiteboard for collaborative activities, focusing on DNA Replication concepts. Key stakeholders included Special Education Case Managers, who provided insights on supporting diverse learners, and Testing Coordinators, who were interested in the alignment with Nevada Academic Content Standards (NVACSS HS-LS1-1) and end-of-course Criterion-Reference Test benchmarks.

Data collection employed both quantitative and qualitative methods. Quantitative data was gathered through a pre-test (administered via Quizizz) and a post-test (15-item objective quiz in Canvas) and analyzed using the Wilcoxon Signed-Rank Test. Quantitative and qualitative data was collected through an end-of-lesson Google Form survey featuring Likert scales, multiple-select questions, and short-answer responses to assess students' attitudes and perceptions toward the digital collaborative tools, which were analyzed using thematic analysis. The implementation was scheduled for April 7-10, 2025, with each class period lasting 82 minutes.

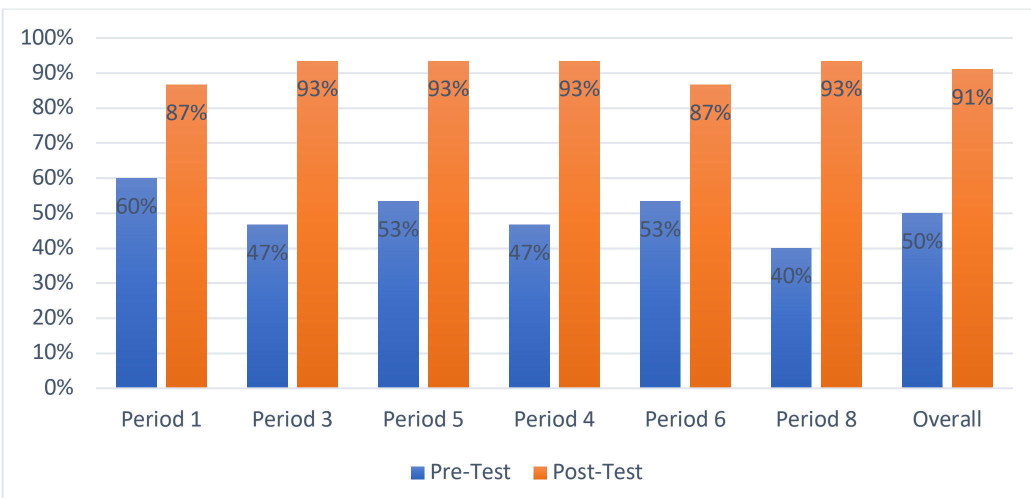
Summary of Results

Test Scores

Figure 1 illustrates the improvement of student knowledge of DNA Replication concepts after completing the designed e-learning module. Data analysis from 24 participants revealed a marked improvement in assessment scores, with mean performance increasing from an initial 50% to 91% post-intervention. The data indicate notable variance in baseline knowledge across class periods, with Period 8 demonstrating the lowest initial assessment scores (40%) and Period 1 exhibiting the highest pre-intervention performance (60%). Post-intervention assessment data showed considerably less variation, with scores clustering between 87% and 93%, suggesting the e-learning module effectively standardized student understanding across all periods.

Figure 1

Comparative Pre-Test and Post-Test Average Scores



Wilcoxon Signed-Rank test (Table 2) confirmed the statistical significance of these improvements. Every period showed higher scores after the intervention, with pre-test scores ranging from 6 to 9 points and post-test scores consistently reaching 13 to 14 points out of a possible 15. The statistical analysis strongly supports the effectiveness of the intervention. The test produced a Z-value of

-2.2014 and a critical value for W with N=6 at the 0.05 significance level of 0. Hence, these results provide strong evidence that the educational intervention successfully enhanced student knowledge of DNA Replication concepts. All periods showed positive change, with the smallest improvement being 4 points (Period 1: 9 to 13) and the most significant improvement being 8 points (Period 8: 6 to 14). Most periods reached a final score of 14, and the consistency of improvement across all periods strengthens the conclusion.

Table 2

Wilcoxon Signed-Rank Test Results of Students' Test Scores

N (6)	Pre-Test Score (M)	Post-Test Score (M)	Sign	Abs	R	Sign-R
Period 1	9	13	-1	4	1.0	-1.0
Period 3	7	14	-1	7	4.5	-4.5
Period 5	8	14	-1	6	3.0	-3.0
Period 4	7	14	-1	7	4.5	-4.5
Period 6	8	13	-1	5	2.0	-2.0
Period 8	6	14	-1	8	6.0	-6.0

Note. With a 0.05 significance level

Student Attitude Survey

The survey aimed to evaluate student motivation, engagement levels with lesson activities, challenges encountered, and student suggestions, as well as how it helped them develop their knowledge of DNA concepts after the intervention. Out of 24 sampled participants, only 22 (91.67%) completed the end-of-lesson survey. The statistical findings of the responses are as follows.

The graphical representation (Figure 2) illustrates the distribution of students' responses to the Likert scale questions from the student attitude survey. Overall, most of the students are motivated (45.5%) to succeed in the lesson. The majority of the students (50.0%) expressed their satisfaction with the teaching methods employed in this e-learning module and felt engaged throughout the implementation of the intervention. However, most of them (50.0%) expressed that they are fairly confident with their mastery of the lesson about DNA Replication.

Figure 2

Student Responses for Likert Scales Questions

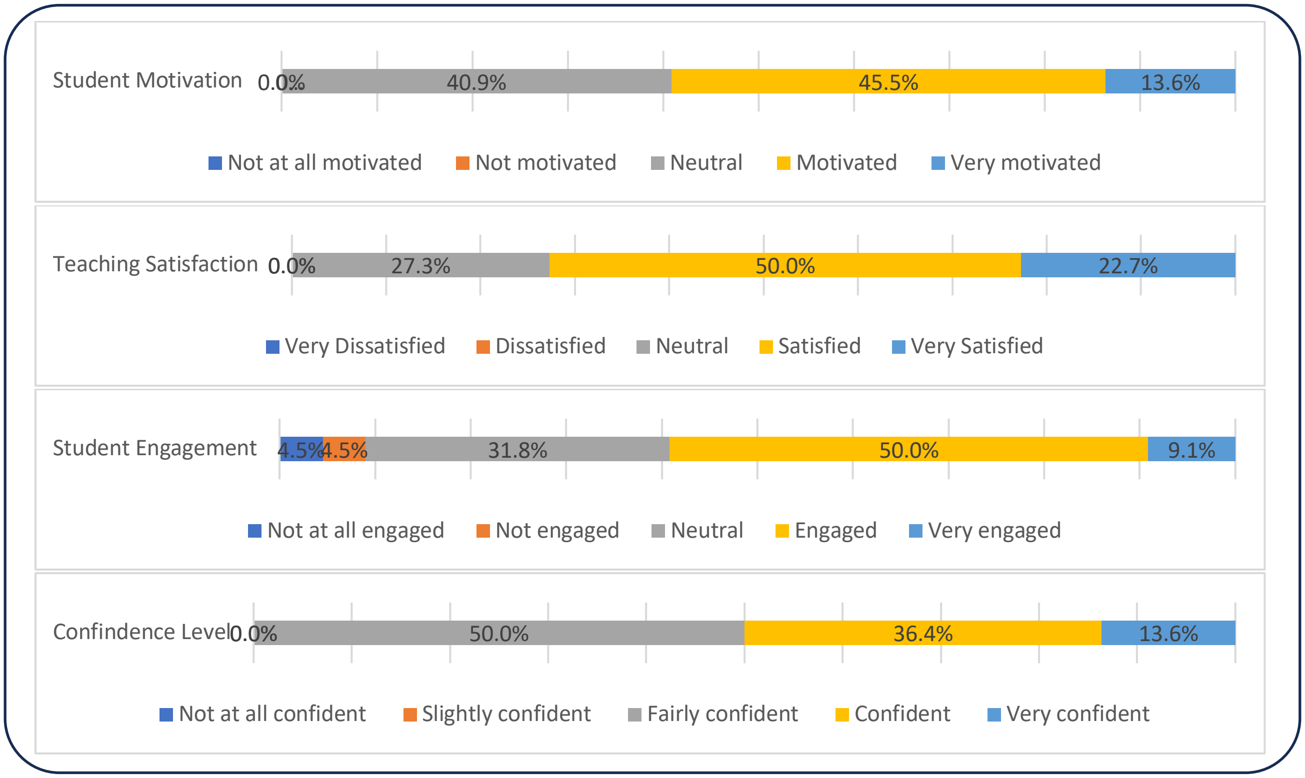
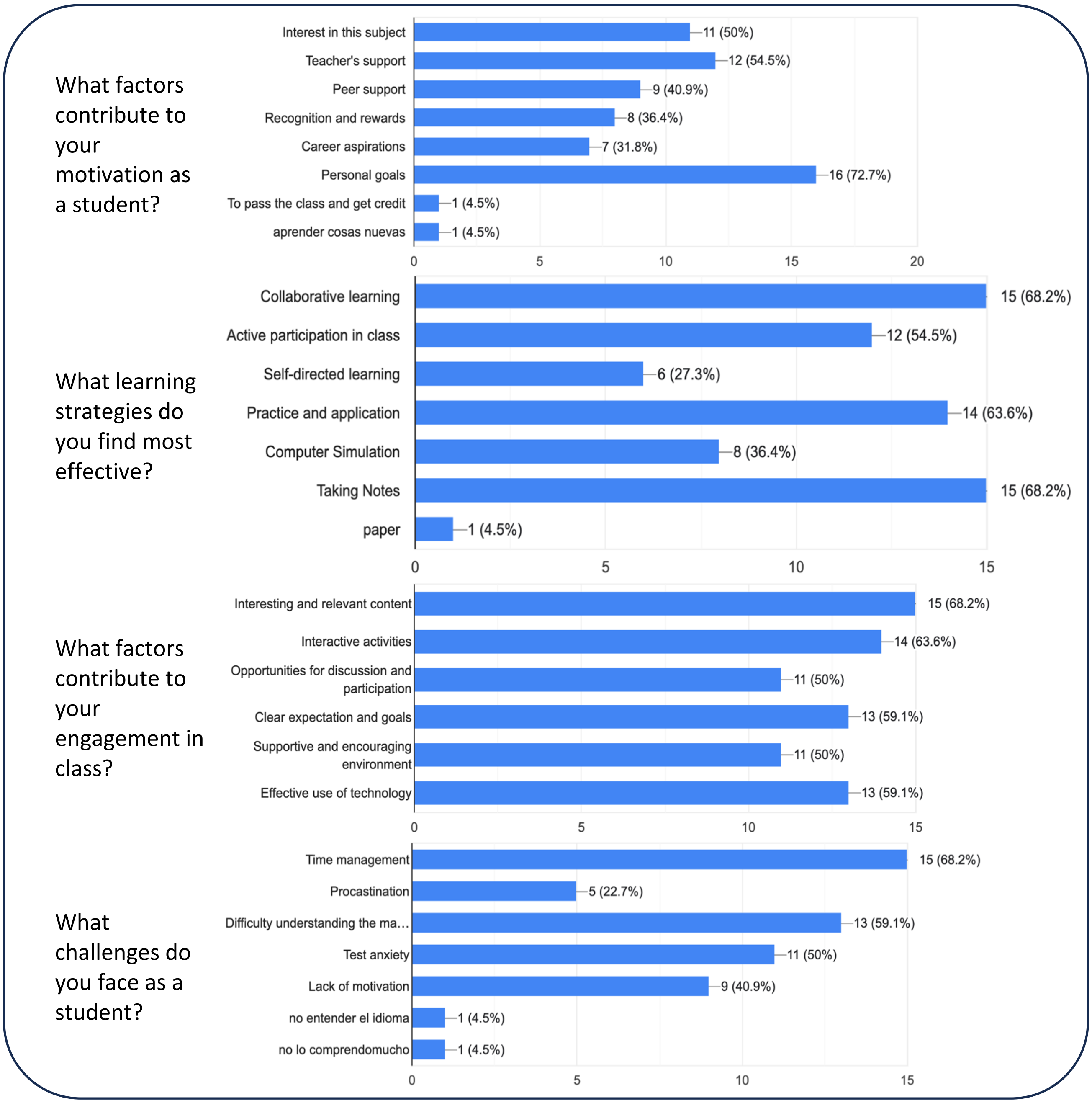


Figure 3 illustrates students' responses to multiple-select questions from the attitude survey. The findings indicate that personal goals (16, 72.7%) are the primary motivator for academic success. Teacher support (12, 54.5%) emerged as the second most influential motivator, followed by interest in the subject (11, 50%). While some of them want to pass, get credit, and learn something new (1, 4.5%). In terms of learning strategies, students demonstrated strong preferences for collaborative learning and note-taking (15, 68.2%), practice and application assignments (14, 63.6%), and active class participation (12, 54.5%). However, traditional paper assignments were reported as least effective, with only 4.5% of students finding them beneficial. The data on class engagement factors revealed that content relevance and interest (15, 68.2%) and interactive activities (14, 63.6%) were the most significant contributors. Clear expectations and effective use of technology (13, 59.1%) both garnered substantial bearing.

Concerning academic challenges, time management (15, 68.2%) emerged as the predominant concern, followed by difficulty in understanding the material (13, 59.1%) and test anxiety (11, 505%). Language or lesson comprehension issues were minimal, reported by only one student (1. 4.5%).

Figure 3

Student Responses for Multiple-Select Questions



Based on the student responses regarding improving their learning experience, three main themes emerged from the analysis (Table 3). First, students desired more collaborative learning opportunities, explicitly requesting smaller group or pair activities and additional support. Second, time management emerged as a significant concern, where students indicated they needed more time to complete and turn in work and better spacing between activities. The third and most diverse theme centered around the differentiation of activities, where students requested various engaging approaches to learning. These included simulation activities, interactive assignments, structured note-taking opportunities, paper-based assignments, experiments, and physical interactive activities. The responses generally indicate that students prefer a varied, interactive learning environment with adequate time for completion and opportunities for peer collaboration.

Table 3

Student Responses for Open-Ended Questions

Question	Theme	Code
What changes or improvements would you suggest to enhance your learning experience?	Incorporate more small group collaboration	Small group
		Need more support
		Pair work
	Increase time allotment for activities	More time
		Time turning-in work
		Space out activities
	Differentiate activities	Simulation activities
		Interactive assignment
		Note-taking
		Assignments in paper
		Experiments
		Physical interactive activities
What additional support or resources would you like to have access to as a student?	Online and paper materials	Websites
		Note-taking
		Provide notes
	Mentorship	Teacher support
		Motivation
		Partner to work with
		Talk 1 on 1
	Additional time	More time

Based on the student responses to "What additional support or resources would you like to have access to as a student?" three primary themes emerged from the analysis (Table 3). The first theme focused on additional online and paper resources, where students specifically requested access to websites and expressed interest in note-taking support, with some explicitly asking for provided notes. The second and most detailed theme centered around mentorship opportunities, where students desired various forms of personal support, including teacher guidance, motivational support, partners to work with, and one-on-one conversations. This mentorship theme emphasized the importance of human connection in the learning process, with partner work mentioned twice in the responses. The final theme related to additional time, which two students mentioned, suggests that time constraints continue to concern learners. It's interesting to note that these responses align with a balanced approach to support, combining digital and physical resources with human interaction and appropriate time allocation.

Minimizing Bias in Data Analysis

This research demonstrated several important strategies for minimizing bias that I recognize when analyzing data about learners. First, the sampling method utilized was carefully designed to ensure fair representation. I used random proportional stratified sampling, selecting four students from each class period to create a balanced sample that included regular education students, English Language Learners (ELLs), and students with Individualized Education Programs (IEPs). This approach helped prevent selection bias that might have occurred with convenience sampling.

To minimize measurement bias, this study utilized a mixed-methods approach combining both quantitative and qualitative data collection tools. Quantitative data came from standardized pre-tests and post-tests, while qualitative insights were gathered through structured Google Form surveys. This combination provided a more complete picture of student performance and experiences while reducing the potential for single-method bias. Moreover, the statistical analysis utilized the Wilcoxon Signed-Rank

Test, which is a non-parametric method that makes fewer assumptions about data distribution than traditional parametric tests. This choice helped minimize statistical bias by accounting for both the direction and magnitude of changes in student performance, providing a more valid analysis of the intervention's effectiveness. The survey design itself incorporated multiple response types, including Likert scales, multiple select questions, and open-ended responses, allowing students various ways to express their experiences and opinions. The high response rate (91.67%) suggests that the data collection method was accessible to most participants.

Proposed Iteration(s) of E-Learning Solution

During the implementation of the e-learning module, I observed that students appeared engaged in their collaborative activities, working together and sharing ideas. However, while observing these groups in action, I realized it was challenging to fully measure the effectiveness of collaborative learning strategies without a comparison class serving as a control group. I could see students actively participating, but I couldn't definitively say whether this learning strategy was more successful than traditional approaches since I had no point of comparison. Reflecting on my research methodology, I recognize essential things to consider in strengthening my study's validity. By implementing stratified sampling, I can maintain a balance in demographics and ability between groups, which will reduce selection bias. A critical refinement would be expanding the research design to incorporate a control group that will receive traditional instruction while comparing their results to the experimental group, which will use the designed collaborative e-learning module. By refining my research approach, I can collect more reliable data and draw stronger conclusions about how collaborative learning strategies impact student understanding of DNA Replication. Implementing a control group should begin using the same random proportional stratified sampling method to divide students into two comparable groups: experimental and control groups. The control group implementation would maintain identical pre-test and post-test conditions for both groups, addressing the document's noted concern about test administration consistency. Both groups should receive the same number of attempts and time limits, with appropriate student accommodations. The experimental group would engage in my designed collaborative e-learning module during the two-block periods, while the control group would receive traditional instruction covering the same material within the same timeframe. Table 4 shows the detailed proposed iteration of the e-learning solution based on my observations and research findings.

Table 4

Detailed Proposed Iteration of the E-learning Solution

Component	Element	Description
Research Design	Experimental Design	• Control and experimental groups • 6-8 day duration • Accommodates IEP requirements
	Sampling Method	• Random proportional stratified sampling • Balanced demographic representation • Equal distribution across periods
Implementation Procedures	Experimental Group	• Enhanced e-learning module • Interactive digital activities • Small group configurations (2-3 members) • Peer support mechanisms
	Control Group	• Traditional instruction • Standard lecture format • Individual assignments • Traditional resources
Assessment	Formative	• Pre-test • Extended time accommodations • Discussion Board • Multiple format options • Progress tracking metrics
	Summative	• Post-test • Extended time accommodations • Collaborative activity • Open-ended feedback
Support Systems	Academic Support	• Teacher guidance • Peer collaboration • Resource accessibility • Flexible scheduling
	Technical Support	• Digital resource access • Format alternatives • Technical assistance

Data Collection	Quantitative Data	• Pre- and Post-Test scores • Completion rates • Participation metrics • Time-on-task measures
	Qualitative Data	• Multiple-point survey responses • Observation notes • Student feedback • Engagement indicators
Data Analysis	Statistical Analysis	• Wilcoxon Signed-Rank Test • Comparative analysis • Effect size calculations • Significance testing
	Thematic Analysis	• Response coding • Pattern identification • Cross-group comparisons • Trend analysis
Timeframe	Regular Schedule	• Initial assessment • Implementation phase • Progress monitoring • Final evaluation
	With Accommodations	• Extended time provisions • Flexible deadlines • IEP accommodations • Modified pacing options

Moreover, I observed that the initially assigned schedule needs adjustment to serve all students better. The rigid four-day timeline doesn't adequately support all learners. Several students have Individualized Education Programs (IEPs) that specify extended time modifications of 1.5x or 2x for assignments. Additionally, I noticed that all students would benefit from more flexible scheduling when completing surveys. This adjustment would ensure that all students can complete their work according to their learning needs and accommodations. I realized that extending the four-day schedule to accommodate IEP requirements was necessary. This refinement is not just a preference but a legal obligation to provide extended time accommodation (1.5x or 2x) for students with IEPs. I understand that consulting with special education Case Managers assigned to my students would be beneficial in implementing these accommodations effectively. By extending the timeline, I would ensure that all students can demonstrate their actual knowledge, as my goal is to assess what they know rather than their speed of completion. I recognize that by properly accommodating IEP requirements, I can create an inclusive environment where all students can fully participate with flexible scheduling that helps reduce stress and removes potential barriers to participation. I must also consider that social desirability bias could emerge when collecting data through test scores and surveys if students focus solely on completion.

Chapter 5: Discussion

Conclusion(s) Based on Results

Students' Learning Outcomes

The implementation of collaborative learning strategies through e-learning modules demonstrated remarkable effectiveness in enhancing student comprehension of DNA Replication concepts. Analysis of data from 24 participants revealed a significant increase in assessment scores, with mean performance rising from 50% pre-intervention to 91% post-intervention. This 41-percentage point improvement was validated through the Wilcoxon Signed-Rank test ($p \leq 0.05$, $Z= -2.2014$), confirming the statistical significance of the results. A particularly noteworthy finding was the narrowing of performance gaps between class periods post-intervention. While initial scores showed considerable variation (40% to 60%), final assessments displayed a more consolidated range (87% to 93%). This convergence suggests that the collaborative approach effectively standardized student understanding across different class periods.

These findings strongly indicate that when implemented through structured e-learning modules, collaborative learning strategies can significantly enhance student mastery of complex biological concepts. The uniformity of improvement across all periods suggests that this approach could be effectively replicated in similar educational contexts.

Students' Perceptions in Using Digital Collaborative Tools

The qualitative findings from the student attitude survey, which achieved a 91.67% response rate, provided additional insight into the intervention's effectiveness, with 45.5% of students reported as motivated and 50% expressed satisfaction with teaching methods and engagement throughout implementation. Personal goals, teacher support, and subject interest emerged as key motivating factors, while students showed strong preferences for collaborative learning, note-taking, practice, and application assignments, and active class participation. However, the study also identified important areas for improvement, with time management emerging as the predominant concern, followed by difficulty understanding material and test anxiety.

The thematic analysis of student feedback revealed comprehensive insights into their learning preferences and needs. When asked about suggested improvements and desired support, students articulated several interconnected themes that paint a picture of their ideal learning environment. In terms of collaborative learning, students expressed a strong desire for enhanced peer support systems and specific opportunities for pair work. This preference for collaborative approaches was closely tied to their time management concerns, where students consistently highlighted the need for extended completion times, more flexible submission deadlines, and better spacing between learning activities. The analysis also uncovered a clear preference for differentiated learning activities, with students requesting a mix of simulation activities, interactive assignments, structured note-taking opportunities, traditional paper-based work, experiments, and physical interactive activities.

When discussing additional support and resources, students emphasized three main areas of need. First, they expressed interest in comprehensive learning materials, including access to relevant websites, note-taking support, and provided notes. Second, mentorship emerged as a crucial theme, with students seeking teacher guidance, motivational support, partner work opportunities, and one-on-one discussions. Finally, time considerations remained a consistent thread throughout their responses, with students requesting additional time allocation for tasks and more flexible scheduling options. These themes demonstrate clear interconnections, suggesting that students value a balanced learning environment that combines collaborative opportunities with adequate support and resources. The relationship between these elements indicates that collaborative learning enhances mentorship opportunities, time management issues directly relate to scheduling considerations, and activity differentiation works synergistically with learning materials. This feedback provides valuable insights for improving the collaborative learning environment while maintaining support for diverse learning needs and preferences, ultimately suggesting that a multi-faceted approach to learning support would best serve the student population.

Based on these findings, the research recommended several refinements for future implementation, including the addition of a control group for more robust comparison, extended timelines to accommodate IEP requirements, more flexible scheduling for assignment completion, increased small group collaboration opportunities, and differentiated activities to maintain engagement. While the results strongly support the effectiveness of collaborative learning strategies in enhancing student understanding of DNA Replication, they also highlight the importance of continued refinement in implementation to better address diverse learner needs and time management concerns.

Limitations

The research encountered several limitations during data collection and analysis that could impact the effectiveness of the e-learning module. A primary limitation was the absence of a control group, which made it challenging to definitively measure whether collaborative learning strategies were more effective than traditional approaches, thus limiting the ability to draw strong causal conclusions about the intervention's effectiveness. The study's sample size was restricted to only 24 participants (four students per class period), which may not fully represent the diversity of learners, potentially affecting the generalizability of findings. While the survey response rate was high (91.67%), two students did not complete the end-of-lesson survey, possibly withholding valuable insights about the intervention. Time management emerged as a crucial limitation, as the initial four-day implementation schedule proved inadequate, particularly in accommodating IEP requirements for 1.5x or 2x extended time, which may have impacted the quality of student work and participation. The study also faced potential bias issues, including social desirability bias in survey responses and implementation bias due to the researcher serving as both teacher and investigator. Technical limitations further complicated the implementation, as some students didn't consistently bring their Chromebooks or had devices that weren't fully charged, while internet connectivity issues slowed down students’ pacing in learning activities.

Implications of Research on Educational Practice

Research findings have identified several interconnected design principles for educational implementation. At its core, an ideal collaborative learning structure suggests small groups of 2-3 students with clear roles and peer support mechanisms, balancing group work with individual accountability. This foundation is enhanced by differentiated instruction that offers multiple content delivery formats and flexible scheduling to support diverse learners. Time management emerges as a critical component, incorporating extended durations for IEP accommodations (1.5x or 2x), buffer time for technical issues, and flexible deadlines. The technology integration principle ensures accessible digital resources with both online and offline options, supported by robust technical assistance. Support systems are carefully structured through teacher guidance protocols and peer collaboration opportunities, while student engagement is maintained through interactive digital activities and real-world applications. Data collection follows a systematic approach with multiple assessment points using both quantitative (objective) and qualitative (performance, open-ended) measures. Accessibility measures ensure IEP compliance and multilingual support, creating flexible learning pathways for all students. Quality control is maintained through clear success criteria and regular checkpoints, with continuous improvement mechanisms in place. These principles work together to create an effective learning environment that maintains high academic standards while accommodating diverse student needs. Regular review and stakeholder feedback ensure the system remains responsive and effective, leading to improved student engagement, enhanced learning outcomes, and increased satisfaction across the educational community.

This design-based research study reveals important implications for education and future research. For learning design, the findings show that structured collaborative approaches work well in science education, especially when using digital tools like Canva Whiteboard, Canvas, and Quizizz to support student interaction. The study highlights the need to balance group work with individual accountability and emphasizes having flexible technology solutions with backup plans for technical issues. Looking at research implications, future studies would benefit from including control groups, longer implementation periods, and more thorough data collection methods. The mixed-methods approach proved valuable, suggesting future research should explore long-term impacts of collaborative learning and optimal group formations. In terms of educational practice, the study supports moving from traditional to collaborative learning approaches, with an emphasis on student-centered strategies. It demonstrates how technology can support diverse learners through multilingual options and flexible learning paths. Moreover, this study particularly highlights implications for equity and inclusion, demonstrating how technology can support diverse learners through multilingual support and flexible learning pathways. The broader educational impact of the study encompasses student success through improved academic outcomes and engagement, the validation of digital tools in modern education, and the importance of educational equity through accessible and inclusive practices. These findings provide valuable insights for educational practitioners, curriculum designers, technology developers, policy makers, and researchers, suggesting that collaborative learning strategies, when properly implemented with appropriate technological support and consideration for diverse learner needs, can significantly enhance educational outcomes and student engagement. The research ultimately contributes to our understanding of effective collaborative learning strategies, technology integration, support for diverse learner needs, data-driven educational practice, and inclusive educational approaches, offering a comprehensive framework for future educational development and implementation.

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