

THE EFFECTS OF COOPERATIVE LEARNING ON STUDENT ACHIEVEMENT
AND COMMUNICATION IN THE BIOLOGY CLASSROOM

by

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of

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DEDICATION

I dedicate this research to my wonderful husband, Samuel Birkett. He was instrumental in my Capstone process, as he supported me as I spent an extensive amount of time and effort on this research. I could not have completed this research without his unwavering support. Thank you, Samuel.

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ABSTRACT

This research was aimed to determine the effectiveness of cooperative learning strategies on student achievement and student communication skills. Students commonly struggle to communicate with one another effectively, which is a necessary skill in their adult lives. To analyze student communication and achievement, 60 students were given two separate treatment units and one nontreatment unit. One treatment implemented the jigsaw method and the second treatment implemented the sage and scribe. Students were assigned random partners multiple times in each unit, so students were working with more than one person during the treatment. During the treatment and nontreatment units, students received a pre-test and pre-survey, to analyze any academic growth as well as student opinions and feelings on group work. A Teacher Journal was kept for the treatment and nontreatment units and was used for thematic analysis. Student surveys were used for student quotes. The jigsaw method was found to increase student test scores by 33%, however a paired t-test determined there was no significant difference in improving student test scores. Student communication skills improved during the jigsaw method. The sage and scribe improved student test scores by 32%, however a paired t-test determined there was no significant difference. Student communication decreased during the sage and scribe. The results of the study suggest that the jigsaw method was more effective than the sage and scribe at improving student communication skills and student achievement.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

I teach an introductory sophomore biology course and a secondary upperclassmen biology course at Charles M Russell High School (CMR) in Great Falls, Montana. The student population at CMR is 1,400, which averages to 350 students per grade level (C.M. Russell High School, n.d.). The school ethnicities from the 2022-2023 school year were reported as 70.6% White, 16.5% Native American, 7.6% Hispanic, 4% multiracial, 1.1% African American, 0.19% Asian, and 0.01% Pacific Islander (Great Falls Public Schools, 2024). Our school motto is, CMR - A better place to learn and teach where relationships, learning, and accountability lead to success. I believe our school embodies this motto, as mental health is prioritized as equal to learning. If a student is struggling in class, we are able and encouraged to send the student to their counselor. CMR also partakes in the Character Strong curriculum during the school day to encourage students' good behavior and mental health awareness. Character Strong lessons require students to examine their current character traits and challenge them to be intentional in their actions. Prioritizing mental health is extremely important, as a person's basic needs must be met before they can process new ideas (McLeod, 2025).

I began my teaching career in the 2021-2022 academic year using primarily note packets and lectures, as I had received in my own high school setting. The introductory biology textbook that CMR utilized was set up in the 5E method, which stands for Engage, Explore, Explain, Elaborate, and Evaluate (Gerges, 2022). I followed the textbook suggestions for teaching the

content by asking questions that connect to the real world. We moved quickly from notes by lectures, to activities, then to assessments. I did not factor in time for retrieval practice, which is time to recall information learned in the past. Students would listen to the material, take some notes, and then be expected to know the content deeply with very little practice. Further into my first year of teaching, I decided to add more practice with the content by utilizing online educational games. Even with the repetition of games, students were still struggling to understand the content deeply and did not spend time interacting with one another. Over the next two years, I added more activities and games to try to increase student engagement with one another. Despite my best efforts, the same students were engaging, while the rest of the class was off task or not participating in the group activities. There was room for improvement in my classroom, as students still struggled to communicate effectively with one another. I was still looking for ways to enhance my teaching, which led me to start my Master of Science in Science Education degree. I began my Master's degree in the summer of 2024, and incorporated methods of increasing student engagement and retention in my fourth year of teaching.

Over my teaching career, I have noticed that students have a difficult time working in groups effectively. When asked to work in groups, they often struggled to find a partner or looked for the smartest student in class to complete the work for them. Students tended to split the assignment or project in half to get the work done independently. Students gravitated towards others who they knew personally, as they were uncomfortable with change. Even when exposed to cooperative games, only some students communicated with one another. I would like to have seen more student engagement with one another, rather than the same two students discussing the content. I have also noticed the blank faces and silence when I have asked students to turn and

talk with their neighbor. It seemed that students were embarrassed to say the wrong answer to a neighbor, so they remained quiet. Furthermore, they may have been unfamiliar with one another socially and lacked the communication skills to be engaged with one another. School is an environment where students learn critical life skills, and cooperative learning is a skill that all students should have. Students should learn to work with others whom they may not know, as this is common in the workplace. Because they do not have the communication skills to collaborate in productive ways, I wanted to focus on increasing constructive student collaboration.

The purpose of my research was to investigate the effectiveness of cooperative learning on academic achievement and communication skills in biology courses. I focused my project around my sophomore biology class, as sophomores were willing to try new techniques as compared to juniors. At the individual level, students would practice their reading comprehension skills, then join with partners to discuss what they read. At the group level, students would practice their group work skills, including conflict resolution if conflict arose. I also examined the relationship between cooperative learning and communication skills, and potential changes in student opinions about cooperative learning.

Focus Statement/Question

My focus question was, What is the effect of cooperative learning on academic achievement and communication skills in the biology classroom?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Student Communication Skills

Students tend to struggle to communicate with others unless they have grown up with one another. Students look uncomfortable when asked to tell their table-mate what they are thinking in class. Rachel Ehmke (2025) interviewed two doctors of education, who stated that children need practice with in-person communication or they may develop anxiety as adults. Parents hold a critical role in the development of children's communication skills (Joseph, 2021). A study by Litermin Joseph (2021) describes poor face-to-face communication skills between parents and their children due to the increased technology presence. A lack of effective parent communication as technology advances is detrimental to the child's skills. This then affects the communication of children with their peers when they reach high school, because they may not learn social cues at home.

As students are becoming accustomed to communicating via text or social media, nonverbal cues are absent, like facial expressions (Ehmke, 2025). These nonverbal clues are a large portion of verbal and social communication, because they give context to the conversation. A study by Iksan et al. (2011) on university students' verbal, written, and social communication skills displayed the lowest scores in verbal communication. Verbal communication can be practiced during discussions and oral presentations, where students practice speaking, listening, and giving oral feedback. Communication skills on both verbal and nonverbal levels are essential to effective cooperative learning.

Cooperative Learning

Cooperative learning is a method of teaching that focuses on student communication skills. It is a process by which students teach each other while gaining content knowledge and interpersonal skills (Gillies, 2016). An example of cooperative learning is think-pair-share, where students have time to think about a question, pair with another student to talk about the question, and then share their thoughts with the whole class (Cooper et al., 2021). The goal is to have focused group work, where set jobs or learning targets are defined for the students. For assessment purposes, there are multiple ways to ensure students are working together. If students are working as a group, students could be scored based on their individual work as well as how they worked in their group. This makes students accountable for working cooperatively and for communicating with one another effectively. Another way to hold students accountable is to assess students individually, then use the average score as each student's score. Group work without assigned roles can lead to copying to get the assignment done. These students may not be focused on learning the material deeply (Slavin et al., 2003).

An abundance of researchers show support for cooperative learning because it provides the opportunity for student discussion (Slavin et al., 2003). Teachers should keep in mind that students must be taught effective group work strategies. The teacher should describe the qualitative goals of team work and determination of each individual. For example, students could be paired and assigned roles as leader and writer, then change roles. Each student would have a chance to share their thoughts, while hearing their partners' ideas. Then the student pairs could discuss the answers they gave to come to a consensus (Hoorani, 2014). In order to have effective leaders, students must develop skills for encouraging others and skills for developing effective

communication. Student communication skills should be taught before and during cooperative learning. A few examples of cooperative learning are jigsaw learning, game-based learning, Think-Pair-Share, and Kagen Cooperative Learning Structures. These subjects have been studied and tested for years, and have shown great promise in increasing student achievement (Zacharia et al., 2010; Chophel & Norbu, 2021; Akhtar et al., 2024).

Jigsaw Method

Jigsaw learning is a method of cooperative learning where students teach each other content. First, students are broken into home groups where chunks of information are given. In these home groups, students have a chance to read through and teach each other the content, becoming experts. Once students are experts, they move to jigsaw groups, where students who learned different content are able to teach each other new information. After the information is shared, students may go back to the home groups to recap what each individual learned (Pahwa, 2022).

While the jigsaw method can increase student achievement, there are a few issues with the method. The goal of jigsaw learning is for students to develop problem-solving and critical thinking skills. Certain assigned readings may be more difficult to understand, as students may not have the information from reading materials given to other groups. This may lead to some confusion until they meet with their jigsaw groups (Pahwa, 2022). Students might have misconceptions after the jigsaw method because the jigsaw groups may have provided incomplete explanations (Doymus, 2008). If students are struggling, the teacher needs to train students in proper peer discussion and interpersonal skills.

Even with the potential disadvantages of the jigsaw method, overall student achievement can improve as students discuss the information in small groups. Students are able to relay information to other students in simplified and direct ways. The jigsaw method works well when students build mutual trust before beginning the process of the jigsaw method (Zacharia et al., 2010). Mutual trust can be built by teachers assigning low-stakes partner work while consistently rotating partners. Students may doubt others' knowledge if they have limited conversations, so allowing space for students to engage with new peers can help build trust.

Kagan Learning Structures

Kagan Cooperative Learning Structures are another form of cooperative learning where students have specific roles to play in the classroom (Chophel & Norbu, 2021). Kagan Structures are focused on four principles: positive interdependence, individual accountability, equal (or equitable) participation, and simultaneous interaction (Kagen, 2009). Students can be placed into teams where they work together, like the sage and scribe. In this method, students take turns as the speaker while the other student writes. This gives students a chance to practice with one another without the fear of being left behind. The teams are held accountable at both the individual level and team level, so students are willing to engage with one another.

Think-Pair-Share

Another way to increase cooperative learning is by using a strategy called Think-Pair-Share (TPS), where students are given time to think about a question and formulate their response, share their ideas with a partner, then share their combined ideas to the class (Akhtar et al., 2024). Students work together to discuss the content, which can lead to deeper understanding

of the material. TPS focuses on increasing student awareness during instruction, where students analyze higher order questions in relation to the content. To use TPS effectively, teachers should randomize the pairs, so every student has a chance to discuss information with others. Humans tend to stick with familiar people, so switching partners often will increase student interactions in the classroom. To hold students accountable for sharing their ideas, Think-Pair-Share can be modified to Think-Ink-Pair-Share, where students are required to write down their ideas and add to them during the pair session (Texas CTE, 2015). This step can increase the conversation in the pair session, because students can look back at their writing as they are talking to their partner. Students then record their partner's thoughts and share both their own ideas and their partner's ideas with the class. There are multiple studies stating that TPS increases student scores (Bateineh, 2015; Bamiro, 2015; Akhtar & Saeed, 2020). In addition to student achievement, one recent study showed that students also felt more positively about cooperative learning in comparison to traditional teaching methods (Akhtar & Saeed, 2020).

Influence on Educator

Cooperative learning methods can influence teachers' belief systems of education. When put into practice, the methods show an increase in student achievement, and often an increase in student engagement (Akhtar & Saeed, 2020). There are many cooperative learning methods that work effectively in the classroom, like the jigsaw method, Kagan Structures, and Think-Pair-Share (Akhtar & Saeed, 2020; Chopel & Norbu, 2021). When teachers begin cooperative learning, they quickly realize that their teaching method must be adjusted. The questions posed to students should be open-ended, to allow for multiple answers and student discussion (Sharan, 2010). This may be difficult or uncomfortable for teachers beginning the practice of cooperative

learning, as lessons may take more time with a student-led classroom. Students may also feel uncomfortable with the process, but with practice their achievements will be seen (Sharan, 2010). Although there is extensive research on cooperative learning's positive impact on academic performance, there is very little research on its effect on communication skills. In addition, there is a lack of research on the effects of cooperative learning on student communication and student confidence in science classrooms.

CHAPTER THREE

METHODOLOGY

Demographics

This research aimed to determine student achievement when students were exposed to cooperative learning strategies in the high school biology classroom. The treatment groups were composed of three separate periods of varying student populations. Second period was composed of 30 students, with 15 female and 15 male students. One student in second period was a junior, while the rest were sophomores. Four students had 504 plans and three students had Individualized Education Plans (IEP). One student was an English-language learner (ELL). Third period was composed of 22 students, with 14 female and 8 male students. One student in third period was a freshman, one student was a junior, and the rest were sophomores. Three students in third period had 504 plans and three students had IEP plans. Fourth period was composed of 24 students, with 12 females and 12 males, all sophomores. One student had a 504 plan, one student was an English-language learner, and there were no IEP plans in fourth period (Table 1).

Table 1. Class demographics separated by period.

	Period 2	Period 3	Period 4
Gender	15 Females 15 Males	14 Females 8 Males	12 Females 12 Males
Class Year	29 Sophomores 1 Junior	1 Freshman 20 Sophomores 1 Junior	24 Sophomores
IEP Plans	Yes	Yes	No
504 Plans	Yes	Yes	Yes
ELL	Yes	No	Yes

Treatment

To ensure equity to my students, all class periods received the treatment at the same time. I used three units of learning as the treatment or nontreatment. Two units were taught with the treatment and one unit was taught without the treatment, to use as a comparison. The treatment units were assigned a cooperative learning method, like the sage and scribe to learn the content. Afterwards, the class discussed possible misconceptions and clarified the main ideas of the lesson. Students then completed questions based on the lesson with their cooperative learning group. Activities with assigned roles occurred before students were quizzed. The assigned roles were randomized, using a random student generator. During the first treatment unit, students were assigned activities using the cooperative learning method, the sage and scribe. During the sage and scribe, one student was assigned the task of being the speaker, while the other student, the scribe, listened and wrote down the sage's response. The students then switched roles. They used this method multiple times throughout the unit, rotating through different partners. During the next treatment unit, students were assigned activities using the jigsaw method and practiced with this method multiple times. In the jigsaw method, students were assigned different reading passages in their home groups, wrote down their takeaways, and moved to meet with their expert groups to come up with a consensus on the reading. Then students moved back to their home

groups and taught each other what they learned. Students wrote down the information from each group member.

During the nontreatment unit, students experienced mini-lectures with fill-in-the-blank notes. Students were expected to try their notes on their own by reading the textbook and completing the fill-in-the-blank notes. As a whole class, we then annotated the notes. Following the notes, students worked either individually or in student-chosen partner pairs on relevant activities that related to the content. Partner pairs were not assigned roles and students were not instructed on how to work together. Finally, each student completed individual quizzes on the content.

This project received an exemption by Montana State University's Institutional Review Board (Appendix A).

Data Collection and Analysis Strategies

During the unit on protein synthesis, each period received the treatment. Protein synthesis included the structure of DNA and RNA, DNA replication, transcription, and translation. Students received a Likert-style Pre Treatment Student Survey to determine their thoughts on group work before the unit began (Appendix B). The 12 question Pre Treatment Student Survey asked students about their beliefs on group work and their prior experience with assigned jobs during group work. A Likert scale was used for many of the questions, with choices of Strongly disagree (1), Disagree (2), Agree (3), and Strongly agree (4). Open-ended explanations for each Likert score were also recorded. Students were also given a Post Treatment Survey after the unit was completed, and the pre and post surveys were compared using thematic analysis (Appendix C). Students received a 22 question Protein Synthesis Quiz before the treatment, and were given

the same assessment following the treatment (Appendix D). Normalized gains and paired t-tests were calculated to determine the effectiveness of the treatment and statistical significance.

Normalized gains of less than .3 were considered low, gains .3 to .7 were considered a medium gain, and gains greater than .7 were considered high (Hake, 1998). During the treatment, I recorded my findings of on-task behaviors, student conversation levels, and general attitude of the room in a Teacher Journal (Appendix E). During the protein synthesis unit, students were placed in randomly assigned pairs, where they took turns as the sage and scribe during analysis of the notes. One student, the sage, talked as the other, the scribe, listened and wrote down their response. They reversed their roles and the process proceeded. Students then completed a worksheet on the DNA double helix structure, where they practiced with the sage and scribe again. For their final task with this cooperative method, students practiced with whiteboards on DNA replication, transcription, and translation with a partner. One student practiced with DNA replication, transcription, and translation first, while the other watched and took note of their method. Then the scribe coached the sage if necessary, and they switched roles. Students took the Protein Synthesis Test mentioned previously. They received an individual score and a partner score, to promote cooperation. The individual pre and post scores were analyzed with a paired t-test in order to test for statistical significance. A Post Treatment Student Survey was also given (Appendix C). The nine question Post Treatment Survey had a few of the same questions as the Pre Survey, to determine any change in responses. The questions were more aligned with the treatment students received, with questions related to the cooperative learning methods used. The survey data was analyzed for themes. Finally, a Post Treatment Student Interview was given to willing students (Appendix F). Six questions on the group work method were asked. Students

had time to write down their responses in a Google Form, then spoke with me about their responses as I audio-recorded their statements. I recorded observations in my Teacher Journal, focusing on on-task behaviors, student participation, and general attitude of the room (Appendix E). The Student Interviews and Teacher Journal were analyzed for emergent themes by using thematic analysis.

The next unit was on mitosis and the cell cycle. It was taught in the nontreatment method, where students experienced normal class activities. Before the unit began, students took a 20 question Mitosis Quiz to determine their prior knowledge (Appendix G). Students also took the Pre Treatment Student Survey. For the cell cycle, students made a foldable to practice with the stages of mitosis and the processes of each. Students practiced on their own or with a partner. Next, they took fill-in-the-blank notes while reading the book. Students then completed a lab to evaluate the reason cells are small. Students completed a hands-on activity to determine the influence of the shape of the cell on a cell's surface area. Students also learned about stem cells and cancer through videos and online simulations. Finally, students practiced identifying different stages of mitosis and practiced identifying these stages with microscopes. Students took the Mitosis Quiz to determine their understanding of the cell cycle, mitosis, cancer, and identifying the stages of mitosis. This quiz was identical to the pre-test given at the beginning of the unit. The pre and posttests were analyzed with paired t-tests and normalized gains were calculated (Hake, 1998). Students also took the Post Treatment Student Survey. A Teacher Journal was kept for theme analysis by using thematic analysis. The pre and post surveys were analyzed by thematic analysis.

The final unit for this research was on genetics, and students received the treatment. In the genetics unit, students learned about meiosis, homologous chromosomes, Mendelian inheritance, non-Mendelian inheritance, epistasis, and mutations of DNA. Students then completed the 20 question Genetics Quiz pretest (Appendix H). Students received the Pre Treatment Student Survey. Students completed notes by the jigsaw method. Students were randomly assigned sections of the notes to complete on their own. They then met with their expert groups, to confirm their understanding of the notes. Students moved to their home group, where each student took notes on different sections. Students then taught each other about their portion of the notes. Next, they completed a mitosis and meiosis comparison individually. In order to promote students teaching one another, students were given an individual score on the Genetics Quiz as well as a home team quiz, where their individual scores were averaged. The Genetics Quizzes were analyzed by paired t-tests and normalized gains were analyzed (Hake, 1998). Students also completed a voluntary Student Interview. Students also completed the Post Treatment Student Survey. As the learning took place, I recorded data in a Teacher Journal. The interviews, Teacher Journal, and surveys were analyzed for emergent themes by using thematic analysis. In order to answer the focus question completely, multiple data sources were analyzed (Table 2).

Table 2. Data triangulation matrix.

Focus Question	Data Source 1	Data Source 2	Data Source 3	Data Source 4
What is the effect of cooperative learning on academic achievement and communication skills in the biology classroom?	Likert-style survey on opinions of group work, Pre and Post Treatment	Student Interviews on views of the cooperative learning methods on their education	Teacher Journal to record student interactions	Pre and posttest on biology content

CHAPTER FOUR

DATA ANALYSIS: CLAIMS AND EVIDENCE

Results

Results showed mixed results on the effectiveness of cooperative learning methods like the jigsaw method and the sage and scribe. Student achievement increased from pre to posttests for both the jigsaw unit and the sage and scribe unit, yet neither of the increases were statistically significant when compared to the nontreatment unit. The jigsaw method increased student communication, while the sage and scribe decreased student communication.

The Jigsaw Method

The jigsaw method did not significantly improve student test scores. A paired t-test was conducted and the p value was .55. The data collected displayed higher average posttest to pre-test scores, however the mean normalized gains of the jigsaw method were .52 and the nontreatment normalized gains were .57 (Figure 1) (Hake, 1998). While the normalized gains depict a medium growth in learning, there is no statistical difference between the nontreatment and jigsaw treatment group (p value = .55). The normalized gains were compared for each student. The nontreatment gains and sage and scribe gains were more consistent as the interquartile range is smaller, indicating the gains are more consistent and less dispersed. The jigsaw method displays a larger range of gains (Figure 1).

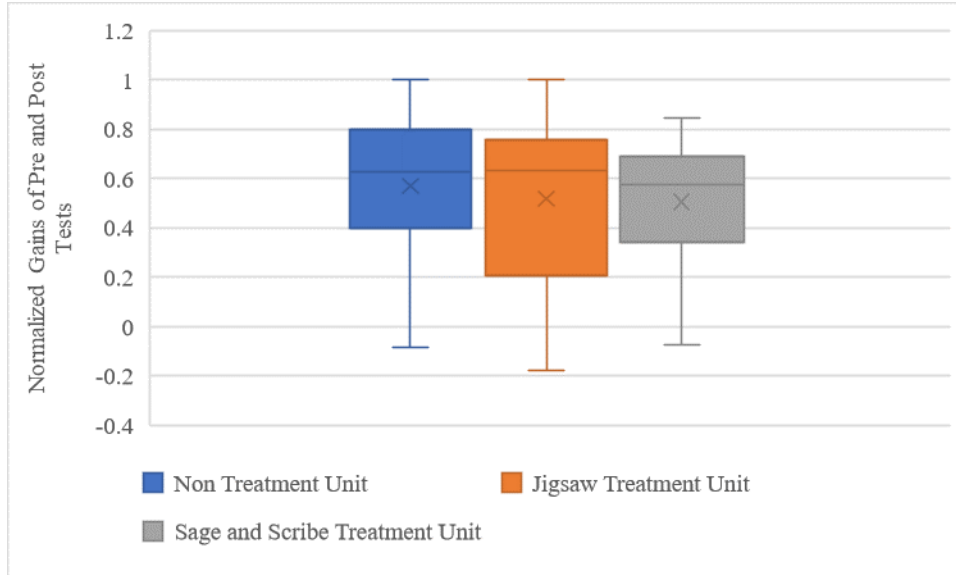


Figure 1. The normalized gains of the pre and posttests for the nontreatment unit, jigsaw treatment unit, and sage and scribe unit ($n = 34$).

During observations of students during the jigsaw method, students were focused on getting their work written down, so they read quietly. A few students were off task, talking with one another or asking clarifying questions about their task. When students were asked to discuss the content, there was a medium volume of voices, where each student could be heard. Some groups communicated better than others, either by familiarity or confidence. During the home groups, students were to read on their own for 10 minutes and write down their thoughts about the passage. Each group did this exceedingly well. When the students were working in groups, the classroom was silent. All students were interested in their reading and note-taking in the home groups and were on task, but very few students enjoyed discussing their summaries together. The volume during discussion ranged from silent to a normal volume (can hear most students well). There was a noticeable difference in student conversation between the jigsaw groups and home groups. Student volume when in home groups ranged from silent to a whisper volume. Student participation during home group discussions decreased over time, as

documented in the Teacher Journal through counts of individual students actively engaged in discussion. Student participation in the home groups was defined by discussing content with one another. The number of students participating in their home groups decreased from day 1 to day 2 (Figure 2).

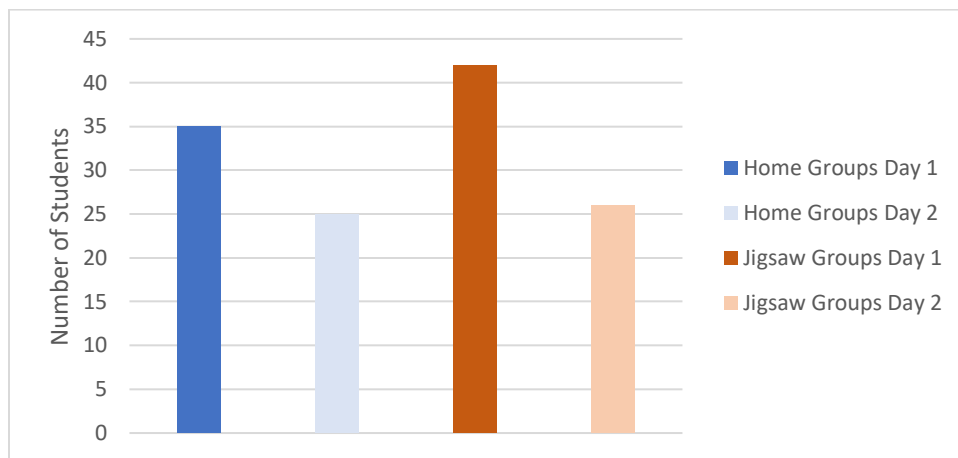


Figure 2. Results of student participation via discussion during the jigsaw method as counted in the Teacher Journal, ($N = 44$).

When students were prompted to continue the conversation in home groups, a majority of the groups said “we already talked” and did not continue their conversations. While the participation in discussion decreased, students were able to communicate what they had learned to me. One student said “these scientists used another’s work to make a model of DNA.” The feel of the room during some student discussions in home groups could be described as awkward or uncomfortable, as noted in the Teacher Journal. As the method continued, students became more comfortable in their jigsaw groups, with more time spent discussing at a normal volume. Students seemed comfortable with reading the text and taking notes on what they had read. One student told me that they preferred taking notes this way, instead of reading the book together

while note-taking. Two students said they enjoy reading and taking notes on their own before we review the content together, so they can have time to become familiar with the content. The results of the jigsaw method Post Student Survey indicated that 6% of students strongly agreed and 66% of students agreed that the assigned jobs during group work kept them on task ($n = 32$) (Figure 3) (Appendix C).

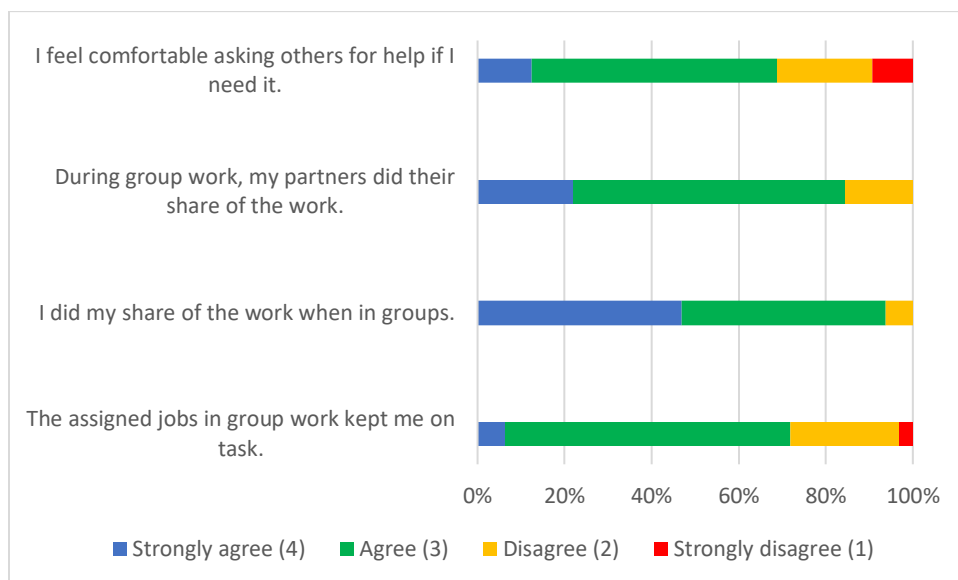


Figure 3. Results from the jigsaw method Post Student Interview. Percent distribution of Post Survey data on the jigsaw method, questions 4, 5, 6, and 9, ($n = 32$).

One student when surveyed about staying on task said, “I think I get distracted unless I get assigned something to do.” Another student said, “Yes it gave an outline for our the [sic] ensuing conversation.” Of those surveyed, 25% of students disagreed and 3% strongly disagreed that the assigned jobs kept them on track. These students mainly did not explain their answers, but a few mentioned they do not enjoy group work. One student noted, “I wasn’t able to focus when I was working with people I didn’t know because I wasn’t comfortable talking with them.”

Another student said the group work “was okay but if there weren’t assigned jobs I’d be on task.”

Additionally, 47% of students strongly agreed and 47% agreed that they did their share of the work when in groups. One student surveyed said, “I tried and gave it my best effort in every situation.” Another student said, “I took my share and worked hard on my part to complete the group.” After completing a paired t-test, there was no significant difference in responses on students completing their share of the work in the jigsaw method (p value = .714, n = 23).

Alternatively, students’ survey responses about whether their partners did their share of the work before and after the treatment showed there was a significant difference (p value = .0497, n = 23) (Figure 4). While there was a significant difference, the value is close to the .05 threshold.

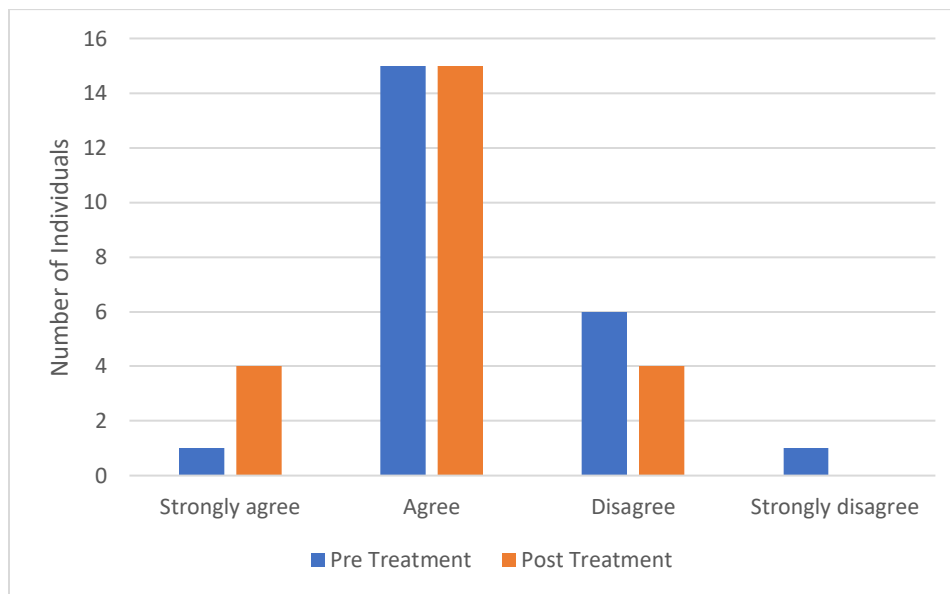


Figure 4. Results from the Pre Treatment Survey and the jigsaw method Post Treatment Survey for question 6, During group work, my partners did their share of the work. The paired responses are on a 4-point Likert scale (1: Strongly Disagree, 2: Disagree, 3: Agree, 4: Strongly Agree). The data shown was used in a paired t-test to calculate significant difference, (n = 23).

According to the Post Treatment Survey, 22% of students strongly agreed and 63% of students agreed that their partners completed their share of the work in the jigsaw method ($n = 32$) (Appendix C). One student surveyed said, “Most people committed to the group unless there were other distractions around.” Students who agreed noted that their partners did their share of the work. One student specifically pointed out that their partner did well communicating. On the other hand, 16% of students responded with disagree. One student said it was dependent on the group, while another student said, “sometimes they did and sometimes they just sat there quietly and did nothing.”

Student interviews revealed that students somewhat enjoyed the jigsaw method, but they would like some modifications. Two students mentioned it would be helpful if there was even more structure, like assigning numbers to each student and instructing who should be talking first. One student mentioned that providing a minimum number of facts required for the assignment would be helpful to keep each student accountable for finding relevant material to write. Two students mentioned having stations around the room instead of reading only one passage may be helpful. One student said they would like time to check other’s information by having additional time to read the other articles. A common theme during the home groups was that there was very little talking among the home groups. Most students said they did communicate better when they were in the jigsaw group, as they had to share their information.

Sage and Scribe

The sage and scribe did not significantly improve student test scores. The data collected displayed higher average posttest to pre-test scores, however the mean normalized gains of the sage and scribe were .51 and the nontreatment normalized gains were .57 (Figure 1) (Hake,

1998). While the normalized gains depict a medium growth in learning, there is no statistical difference between the nontreatment and the sage and scribe (p value = .45).

Students observed during the sage and scribe unit were unhappy with this method of learning and were confused after the roles were assigned. Students seemed agitated to be working on one paper, and consistently struggled to maintain their roles. One period of students did not stick to the roles from the very start, even after multiple redirections. The first day, one class of students were on task for 10 minutes during the period, then students began to take their own notes individually. The other two periods of students were on task for an average of 35 minutes, with an average of 20 students on task. The longer this method was used, student participation fell rapidly. One student told me “that was so uncomfortable, at least the whole class was working quietly.” In the span of one day, student participation in their assigned roles decreased from an average of 16 students to 7 students. Four out of five students interviewed said they would like the method better if they were able to choose their partners. Two students mentioned that students may get off task if they were working with their friends, and would need to be separated. Three students mentioned they did not do their roles properly, but did get their work completed.

In the sage and scribe Post Treatment Survey, 39% of students disagreed or strongly disagreed that their partners did their share of the work (Figure 5) (Appendix C). After completing a paired t-test on Question 6: During group work, my partner did the share of the work, no significant difference was found (p value = .19, n = 25). Students’ Pre and Post Survey responses on Question 9, I feel comfortable asking others for help if I need it, were similar, showing no significant difference (p value = .083). Students said that the sage and scribe method

was “confusing” and “makes no sense.” Student survey responses presented that students believed they were on task, as they were still getting their work done, but not in their assigned roles. One student said “we were on task but we didn’t do the roles.” Another student said “I wish I got a partner that would talk to me.”

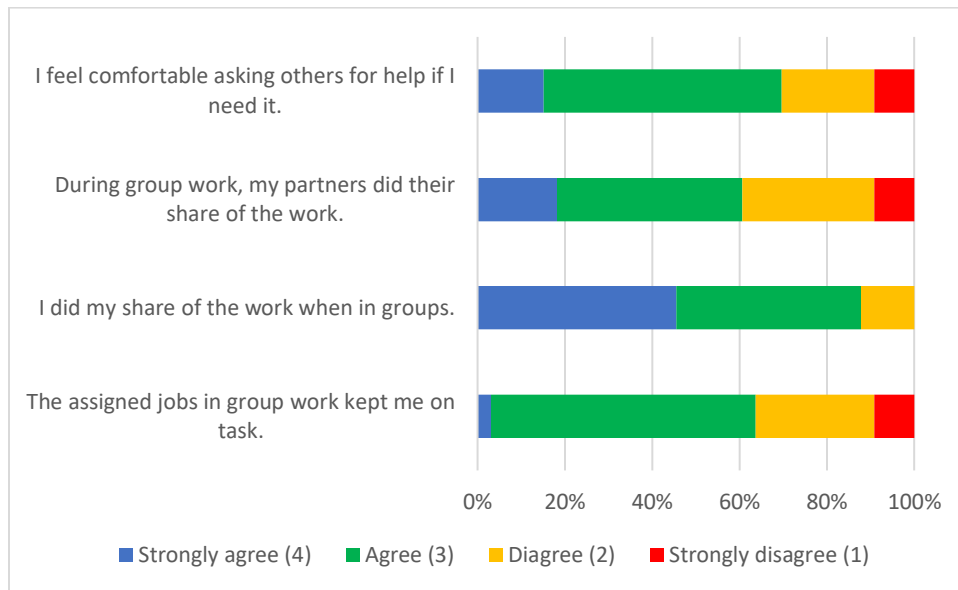


Figure 5. Results from the sage and scribe post survey data on the sage and scribe, questions 4, 5, 6, and 9, ($n = 33$).

CHAPTER FIVE

VALUE: REASONING AND REFLECTION

Claims from the Study

The goal of this study was to determine the effect of cooperative learning methods through both the jigsaw method and sage and scribe on student achievement and student communication skills. To determine student achievement, I analyzed the pre and posttest data of the jigsaw method and the sage and scribe. The jigsaw method led to a large increase in student test scores, from a mean of 34% to 67%, however, this was not statistically significant when compared to the nontreatment unit test scores. Content difficulty between the nontreatment and treatment unit may be a factor impacting the overall test scores. While the jigsaw method showed no significance, observations showed that students were actively discussing content in class. Students were able to communicate consistently during the jigsaw method as shown by the conversation volume increase over time and student interviews.

The sage and scribe led to an increase in student scores, from a mean of 37% to a mean of 69%. However, scores from the sage and scribe unit were not statistically significant when compared to the nontreatment unit scores (p value = .45). Students quickly grew frustrated with the sage and scribe, as students were not communicating with one another, and were more focused on getting their work done. Students quickly abandoned the method and worked individually.

There were some obstacles throughout the study that may have impacted the reliability of the results. Reliability is defined as the consistency of quantitative data (Mertler, 2024). The test-

retest method is not often used in action research, as it takes up valuable classroom time. An internal consistency statistical test, like the Kuder-Richardson formula 21, requires only one test, which can be more useful in classrooms where students are absent often (Mertler, 2024). My study had varying number of student responses for the pre and posttests and surveys, limiting the data I could use in the study. Some students who participated in the study did not complete the surveys or tests, as they were either absent or chose not to complete them. Student test scores were not put into the gradebook, so some students may not have given their best effort in order to finish their test quickly. Additionally, some students provided very little feedback on surveys, as students may not have known how to explain their answers. The random pairing was disrupted for one student, as the administration requested their teachers be mindful of partner pairs due to anxiety. This reduced my randomness of pairing in one class period. Another factor affecting the study was a shuffling of students due to a teacher leaving. All of my classes in the study were affected, with one class moving from 18 students to 30. The other classes gained three students each, and the dynamics of each class changed. Students in one class were uncomfortable from the start, as they had to intermingle with new peers in a full classroom setting.

This study supports previous research on cooperative learning. My study somewhat supports that cooperative learning increases student cooperation and discussion, as Slavin et al. (2003) described. Students did a good job communicating with one another during the jigsaw method, but did not do well communicating during the sage and scribe. I was pleased that students were communicating clearly with one another in their group work during the jigsaw method. Students worked together to complete their tasks and taught one another during the jigsaw method. Although they did not increase significantly, student assessment scores

noticeably increased for both the jigsaw method and the sage and scribe, which aligns with previous studies (Akhtar & Saeed, 2020).

Value of the Study and Consideration for Future Research

Throughout my teaching career, I have looked into ways to help students increase their group work skills and academic achievement. This research process has given me a better understanding of how to evaluate the implementation of new strategies in the classroom. I plan to continue to implement the jigsaw method throughout each unit, as students enjoyed this process of learning. At the beginning of the jigsaw method process, students asked questions on what they were expected to write down. They gained confidence and asked fewer questions as the jigsaw method continued. Even though student achievement did not increase significantly, I still find value in students learning this way, as they have the chance to learn from one another. I believe that if this method is implemented from the beginning of the year and practiced often, there could be a significant difference in achievement.

The sage and scribe led to students working individually, occasionally asking their partner a question. Students did not enjoy this group method, and I will not use this method in the future. This method works best when students are held accountable in their team to increase the student cooperation, as Kagan (2009) described. If team grades are assigned, students may have more interest in participating. Adding sections to assignments labeled Partner 1 and Partner 2 may increase student participation, as there would be more structure and direction.

Further research is needed in the improvement of communication skills between student peers during cooperative learning, as my classroom was changed dramatically at the start of the study. The students that moved into my class tended to chat with students that moved with them.

My original students were very uncomfortable and also tended to work with each other, rather than working with the new students. About seven students interacted with one another from the start of the move. If a scenario similar to this happened in the future, the dynamics in the classroom could be resolved by completing some icebreakers at the beginning of the fusion. This research should be conducted with classes that have experienced little to no student movement during the school year. This would ensure students could become more comfortable working with students they already know during these cooperative learning methods. I believe the jigsaw method has the potential to increase student communication in well-established classrooms, as seen in two classes that are comfortable with one another. To increase student conversation during home groups, low stakes group work could be used to build trust between students before the jigsaw method is implemented as described by Zacharia et al. (2010). Student communication skills, like providing sentence stems for discussions could also help to guide the conversation. Students may have more buy in if they are graded based on their individual work and their group work (Slavin et al., 2003).

Impact of Action Research on the Author

This research process has opened my mind to the complexity behind conducting a study in the classroom. I am grateful for the experience in formulating a study, and I have ideas of how to better complete studies in the future. In the past, I had no experience in collecting data to analyze the new teaching methods I was implementing. I am more confident in the explicit data collection and analyzing data with statistical analysis. While student test scores can be a helpful tool, I found the qualitative data more impactful. I could feel the attitudes in the room shift when students completed their jigsaw activities, with students engaging with one another more than

they have in the past. It was interesting seeing students dislike of the sage and scribe, as they quickly decreased their conversation levels with one another. I have also enjoyed sharing my results with my coworkers. I shared my jigsaw method assignments with a coworker, and plan to share with the rest of the department, as students seemed to enjoy learning in this way.

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APPENDICES

APPENDIX A: MONTANA STATE UNIVERSITY IRB
EXEMPTION

Protocol Information

Version # 1

Reference Number	2402
Protocol Number	2026-2402-EXEMPT
Protocol Title	The Effects of Cooperative Learning on Student Achievement in the Biology Classroom
Protocol Type:	Original
Principal Investigator:	Birkett, Alyssa
Approval Date:	1/26/2026
Submittal Date:	1/23/2026
Effective Date:	1/26/2026
Author:	Birkett, Alyssa
Renewal Date:	1/26/2031
Status:	Approved
Next Review Date:	1/26/2031
Inactive Date:	
Expiration Date:	1/26/2031

Figure A1. IRB approval statement.

APPENDIX B: PRE TREATMENT STUDENT SURVEY

1. I have worked in assigned groups before.

- ☐ Yes
- ☐ No

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

2. I enjoy working in teacher-assigned groups.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

3. I enjoy working in student-chosen groups.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

4. Previous teachers have assigned roles/jobs to students during group work.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

5. I learn best when working with other students.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

6. I enjoy working with others I may not know personally.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

7. I like working with others I know.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

8. When working in groups, I do my share of the work.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

9. When working in groups, my partners do their share of the work.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

10. I work better alone, without student help.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

11. I can solve problems when they arise.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

12. I feel comfortable asking others for help if I need it.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

APPENDIX C: POST TREATMENT STUDENT SURVEY

Please choose the rating that best matches your opinion.

1. I understand the biology content more after learning with other students.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

2. I enjoy working with others I may not know personally.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

3. I like working with others I know.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

4. The assigned jobs in group work kept me on task.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

5. I did my share of the work when in groups.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

6. During group work, my partners did their share of the work.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

7. I learn best when other students help me.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

8. I can solve problems when they arise.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

Please choose the rating that best matches your opinion.

9. I am comfortable asking others for help if I need it.

Mark only one oval.

- ☐ Strongly disagree (1)
- ☐ Disagree (2)
- ☐ Agree (3)
- ☐ Strongly Agree (4)

Explain your answer from the previous question.

APPENDIX D: PROTEIN SYNTHESIS QUIZ

Read each question. Bubble the letter of the correct answer.

1. DNA stores _____.

- A. fat
- B. hereditary information
- C. carbohydrates
- D. energy

2. The center of the two strands of a DNA molecule (between the nitrogenous bases) are held together by _____.

- A. ionic bonds
- B. peptide bonds
- C. hydrogen bonds
- D. covalent bonds

3. Which of the following is not part of a nucleotide in a DNA molecule?

- A. a nitrogenous base
- B. a sugar
- C. a protein
- D. a phosphate group

4. A specific cell is unable to make the enzyme helicase. Because of this deficiency, what would the cell most directly be unable to accomplish?

- A. The cell would not be able to unzip the double helix.
- B. The cell would not be able to add new nucleotides.
- C. The cell would not be able to fix mistakes in the DNA.
- D. The cell would not be able to add the primer to the DNA strand.

5. When talking about the importance of DNA replication, which statement is false?

- A. Replication is needed for a cell to go through cell division.
- B. Replication ensures we have identical DNA in all cells.
- C. Replication is important because it only occurs during embryonic development.
- D. Replication is important because we have to copy our DNA every time we need a new cell.

6. Which of these is not associated with DNA?

- A. thymine
- B. guanine
- C. cytosine
- D. adenosine

7. The four types of nucleotides that make up DNA are named (purines and pyrimidines) for their _____.

- A. hydrogen bonds
- B. nitrogen-containing base
- C. ring-shaped sugars
- D. phosphate groups

8-12- MATCHING choose from these

(A. Chargaff), (B. Watson/Crick), C. Franklin), (D. Avery), (E. Griffith)

8. Who discovered that genes are composed of DNA and not carbohydrate, lipid or protein?

9. What scientist is responsible for base pairing rules (same percentages of A's T's and G's and C's)?

10. Who discovered DNA forms a double helix and made the first model of DNA?

11. Which scientist discovered that a "factor" (DNA) can "transform" harmless mice into disease causing mice?

12. Who (she) was the first to use x-rays to help see the structure of DNA?

13. Proteins are made up of _____.

- A. amino acids
- B. catalysts
- C. ATP
- D. enzymes

14. During transcription, _____.

- A. translation occurs
- B. proteins are synthesized
- C. DNA is replicated
- D. RNA is produced

15. In translation, which of these is responsible for forming a peptide bond between amino acids to make proteins?

- A. ribosome
- B. tRNA
- C. nucleus
- D. DNA

16. At the very beginning of translation, the first tRNA molecule _____.

- A. binds to the mRNA's start codon
- B. binds to the mRNA's anticodon
- C. attaches directly to the DNA codon
- D. connects an amino acid to its anticodon

17. In order to produce all the protein that a cell needs, transcription takes place _____.

- A. using single-stranded RNA
- B. using double-stranded RNA
- C. on a gene segment over and over again
- D. on a gene segment only once

18. What is the name for the portion/part of the DNA that codes for a specific protein?

- A. chromosome
- B. gene
- C. histone
- D. nucleotide

19. A codon is a _____.
- A. protein that blocks DNA transcription
 - B. three-nucleotide sequence that codes for an amino acid
 - C. segment of DNA that speeds up transcription
 - D. DNA segment that allows a gene to be transcribed
20. Which of the following statements is not correct concerning DNA and RNA?
- A. Both DNA and RNA contain the base cytosine.
 - B. Both RNA and DNA are double-stranded molecules.
 - C. RNA contains the base uracil while DNA contains thymine.
 - D. DNA contains a sugar called deoxyribose while RNA contains a sugar called ribose.
21. Which is NOT a type of RNA?
- A. mRNA
 - B. tRNA
 - C. rRNA
 - D. cRNA
22. What is the correct order of the steps of protein synthesis?
- A. translation then transcription
 - B. make RNA into DNA then make DNA into a protein
 - C. transcription then translation
 - D. Transcription and translation occur at the same time

APPENDIX E: TEACHER JOURNAL LAYOUT

Teacher Journal

Record the frequencies of:

Student conversation level

- 1: Low-No volume, quiet
- 2: Low-Medium volume, whispered conversations, can hear each student well
- 3: Medium-Loud volume, normal volume conversations, can hear most students
- 4. Loud, raised voices, cannot hear each student well

Time of on task behavior (minutes)

Number of Students participating in their roles

Record general information

Student quotes

Attitudes/feel of the room

APPENDIX F: STUDENT INTERVIEW QUESTIONS

Student Interview

What did you enjoy about this method of group work?

What do you wish was different about this group work?

Describe three to four of the topics we covered in class to demonstrate your understanding of the biology content after working with your group.

Did you think and feel each student was holding up their end of the work?

What suggestions do you have for group work scenarios?

Is there anything else you would like me to know?

APPENDIX G: MITOSIS QUIZ

1. Which of these is part of the cell theory?
 - A. Most cells arise from existing cells.
 - B. All living things are made of one cell.
 - C. Cells are nonliving units that make up organisms.
 - D. Cells are the most basic units of life.
2. Multicellular organisms use cell division or mitosis for growth, development, and _____.
 - A. repair
 - B. apoptosis
 - C. interphase
 - D. fertilization
3. Which of these terms is not related to the term cancer?
 - A. melatonin
 - B. malignant
 - C. metastasize
 - D. chemotherapy
4. In which scenario would a cell undergo apoptosis?
 - A. a newly formed cell
 - B. a cell that is at the end of G2
 - C. a cell that has reached its full size
 - D. a cell that has damaged DNA and cannot function properly
5. Approximately how long does it take for a cell to divide?
 - A. 2 days
 - B. 2 seconds
 - C. 12 hours
 - D. 12 minutes

6. Which of these shows the correct sequence of events in the cell cycle?
- A. M, G₂, G₁, S
 - B. G₁, S, G₂, M
 - C. S, G₁, M, G₂
 - D. M, G₁, G₂, S
7. A specific cell is a cube measuring 2 units on each side. What would be the cell's surface area and volume?

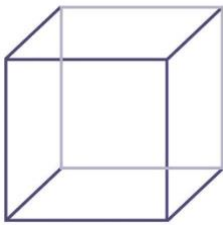


Figure A2. A cube.

- A. 6 and 1
 - B. 6 and 8
 - C. 9 and 9
 - D. 24 and 8
8. Which of the following scientists is credited with coining the term *cells*?
- A. Robert Hooke
 - B. Matthias Schleiden
 - C. Rudolf Virchow
 - D. Theodor Schwann
9. In which stage of the cell cycle do cells stay for years and decades just working and doing their job?
- A. mitosis (M)
 - B. gap 2 (G₂)
 - C. gap 0 (G₀)
 - D. synthesis (S)

10. Two internal factors that are important in advancing the cell cycle are _____.
- A. kinases and cyclins
 - B. proteins and platelets
 - C. hormones and enzymes
 - D. ketamines and cyphalims
11. During which phase of mitosis are chromatids separated?
- A. metaphase
 - B. anaphase
 - C. telophase
 - D. prophase
12. Which part of a chromosome is involved with aging and how many times a cell will divide before apoptosis?
- A. Chromatid
 - B. Telomere
 - C. Centromere
 - D. Kinetochore
13. What happens to cells during differentiation?
- A. They gain the ability to build entire organisms.
 - B. They develop less specific structures and organelles.
 - C. They become stem cells and divide into zygotes.
 - D. They lose the potential to develop into any type of cell.
14. Mitosis is the process by which _____.
- A. the cell rests
 - B. cytoplasm is divided
 - C. microtubules are assembled
 - D. the nucleus is divided into two nuclei

15. How is binary fission different from vegetative reproduction?
- A. Binary fission occurs slowly, while vegetative reproduction occurs rapidly.
 - B. Binary fission occurs in plants, while vegetative reproduction occurs in animals.
 - C. Binary fission is a type of asexual reproduction, while vegetative reproduction is a type of sexual reproduction.
 - D. Binary fission occurs in single-celled organisms, while vegetative reproduction occurs in multicellular organisms.
16. During which phase of mitosis do chromatids line up along the midline?
- A. metaphase
 - B. anaphase
 - C. telophase
 - D. prophase
17. Cells in the body that can divide repeatedly and become other types of cells are called _____.
- A. stem cells
 - B. embryo cells
 - C. connective cells
 - D. reproductive cells
18. How are mitosis and cytokinesis different?
- A. Cytokinesis occurs in plant cells, while mitosis occurs in animal cells.
 - B. Cytokinesis occurs in animal cells, while mitosis occurs in plant cells.
 - C. Cytokinesis is the division of the cytoplasm, while mitosis is the division of the nucleus.
 - D. Cytokinesis is the division of the nucleus, while mitosis is the division of the cytoplasm.
19. Which of the following is not one of the cell layers found in vertebrates?
- A. ectoderm
 - B. mesoderm
 - C. endoderm
 - D. middlederm

20. The pie chart shows the time associated with the stages in the cell cycle.

During which of the stages shown in the chart does copying of DNA (chromatids) occur (going from one chromatid to 2 sister chromatids)?

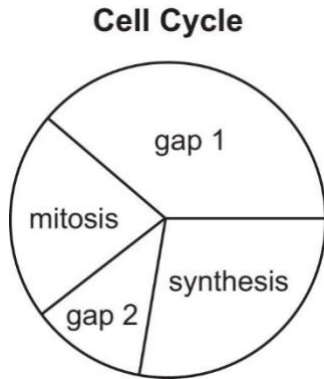


Figure A3. Cell cycle diagram.

- A. gap 1
- B. gap 2
- C. cell division
- D. synthesis

APPENDIX H: GENETICS QUIZ

1. Which event is an important factor in increasing variety among sexually reproducing organisms?
 - A. crossing over
 - B. gene linkage
 - C. testcross
 - D. mitosis
2. Which phrase best describes the process of meiosis?
 - A. occurs in body cells
 - B. produces haploid gametes
 - C. happens only in haploid cells
 - D. results in genetically identical cells
3. Which describes a difference between mitosis and meiosis?
 - A. Meiosis $1 \rightarrow 4$ / Mitosis $1 \rightarrow 2$
 - B. Meiosis $1 \rightarrow 2$ / Mitosis $1 \rightarrow 4$
 - C. Meiosis -identical / Mitosis -different
 - D. Meiosis – everywhere in body / Mitosis –ovaries and testes
4. Which of these is a way to ensure genetic diversity?
 - A. independent assortment at metaphase I.
 - B. independent assortment at metaphase II.
 - C. mitosis at metaphase.
 - D. crossovers at metaphase II.
5. How is gametogenesis different in females from in males?
 - A. Males produce four functional sperm while females produce only one functional egg.
 - B. Males produce only one functional sperm while females produce four functional eggs.
 - C. Males produce four genetically identical sperm while females produce four genetically different eggs.
 - D. Males produce four genetically different sperm while females produce four genetically identical eggs.
6. Separation of homologous chromosomes (pairs) occurs during _____.
 - A. mitosis
 - B. meiosis I
 - C. meiosis II
 - D. fertilization

7. When crossing over takes place, chromosomes _____.
A. decrease in number
B. produce new genes
C. mutate in the first division
D. exchange corresponding segments of DNA
8. What happens to sister chromatids in meiosis II?
A. They duplicate
B. They are divided
C. They do not take apart
D. They remain together
9. In which phase of meiosis does the chromosome number change from diploid (46) to haploid (23)?
A. prophase I
B. anaphase I
C. prophase II
D. anaphase II
10. Which phrase best describes meiosis I?
A. fusion of sister chromatids
B. creation of two diploid cells
C. duplication of paired chromosomes
D. division of homologous chromosomes (pairs)
11. Chromosomes determine all inherited traits because they are made up of _____.
A. ATP
B. DNA
C. centromeres
D. phospholipids
12. All the different forms of a trait are called _____.
A. alleles
B. homologous
C. genes
D. chromosomes

13. If both alleles show up in the offspring like speckling, spots or strips then this would most likely be associated with which of the following?
- A. Polygenic
 - B. Codominance
 - C. Multiple alleles
 - D. Incomplete dominance
14. Which type of inheritance concerns traits that are located on the X chromosome and males get more genetic problems associated with these traits?
- A. polygenic
 - B. sex-linked
 - C. codominance
 - D. incomplete dominance
15. If an individual possesses two recessive alleles for the same trait, the individual is said to be _____.
- A. mutated
 - B. haploid for the trait
 - C. homozygous for the trait
 - D. heterozygous for the trait
16. The law of segregation, where you get half your genetic material from each parent, deals with which of the following?
- A. the separation of alleles during meiosis
 - B. the separation of daughter cells during mitosis
 - C. the separation of homologous chromosomes during mitosis
 - D. the separation of homologous chromosomes during meiosis
17. If a blending of traits occurs in offspring you would most likely associate this with which of the following?
- A. Polygenic
 - B. Codominance
 - C. Multiple alleles
 - D. Incomplete dominance

18. Which of these terms best associates with this: Ww and Wavy hair.
- A. genotype and phenotype
 - B. phenotype and genotype
 - C. homozygous and heterozygous
 - D. purebred and hybrid
19. Which of these was a key factor in the success of Mendel's experiments?
- A. He started with several different types of plants.
 - B. He started with plants that were native to the area.
 - C. He started with cross-pollinating, flowering plants.
 - D. He started with self-pollinating, purebred plants.
20. Mendel's second law of genetics, the law of independent assortment (flip flop of chromosomes at metaphase I), is one explanation of the _____.
- A. final stages of gametogenesis
 - B. random fertilization of gametes
 - C. genetic variation within species
 - D. greater strength of dominant alleles