

AN INVESTIGATION OF FOUR REMEDIATION TECHNIQUES
IN THE SCIENCE CLASSROOM

by

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ABSTRACT

The goal of this research project was to determine which of four teaching strategies was most effective as a remediation technique. The four strategies included table manipulatives, concept mapping, interactive science notebook journaling, and a flipped classroom approach. Over the course of eight instructional units, students were exposed to each strategy twice during a mid-day remediation and enrichment period called the GAELS period. The results of this investigation suggest that each of the four strategies were effective for improving students' test scores from pre to post-test for at least one unit, but some strategies worked better for one unit than another, sometimes producing a large normalized gain for one unit, and a negative normalized gain for another. Overall, concept mapping produced the largest gain from the study, 31%, when used with the cell transport unit.

INTRODUCTION AND BACKGROUND

A few years ago, Bishop Gorman High School, a Roman Catholic high school in Las Vegas, Nevada, instituted the GAELS period. This mid-day remediation and enrichment period was named after our mascot- the Irish Knight, or Gael. Our school's integral student outcomes are based on the GAELS acronym, which at our school stands for: God, Accountability, Excellence, Leadership, and Stewardship. It was the "E" in GAELS that prompted our school leadership to take a look at how we can truly make our school stand out academically in order to continue that tradition of excellence. Academic excellence requires that we hold all students to the same high standards. In order to do this, students who are unsuccessful in their first attempt at mastery are offered additional support until they have successfully mastered material. The school's enthusiasm for mastery learning was the inspiration for my investigation into the best practices for offering support during the GAELS period.

The class chosen for this study was a sophomore college-preparatory level biology class at Bishop Gorman High School in Las Vegas, Nevada. Bishop Gorman High School is a private Catholic high school. Biology classes are divided into college preparatory level, honors level, and scholars level. Students are placed into one of these three classes based on results on a freshman placement exam. College preparatory level biology is the lowest level. There is no "regular" biology option due to the fact that Bishop Gorman is a college preparatory school.

The students who attend Bishop Gorman come from mostly upper-middle class families, although students from families of lower incomes are present in the student population as well. There are approximately 1,500 students at Bishop Gorman, and every

year there is a waiting list of students who hope to join the freshmen class, which means that the school can be selective of the students who attend Gorman. “As a college preparatory school, Bishop Gorman has a 98% college bound rate. The Class of 2016 boasts three National Merit Scholarship Finalists, one National Merit Scholarship Semi-Finalist, eight National Merit Scholarship Commended Students, seven Gold Key Award Winners, and was awarded over \$17 million in scholarships” (Bishopgorman.org school review section para. 2). The school is one of only two catholic high schools in Nevada and the only catholic high school in Las Vegas.

The GAELS period was implemented at the same time that the school adopted the ideas relating to becoming a professional learning community. The first of several big ideas behind professional learning communities is ensuring that students learn. This idea prompts teachers to ask themselves three questions:

1. What do we want each student to learn?
2. How will we know when each student has learned it?
3. How will we respond when a student experiences difficulty in learning? (ASCD.org, 2004).

While many schools define what they want students to learn and spend considerable time designing assessments to assess that learning, the third question is what I believe sets PLC communities, like our school, apart. This is what prompted me to begin asking questions about how we can best suit the needs of learners who require additional time and instruction in order to master the material.

As a school, we’ve adopted a type of mastery learning. When assessments show that students have not mastered the material, students are assigned to complete

remediation, usually during GAELS period, and attempt the assessment again. Mastery learning is built into our school culture and embedded right in the middle of our school day. It has been suggested that mastery-learning strategies help in preventing minor learning gaps from becoming cumulative and resulting in larger learning gaps. When done right, these practices can have overwhelmingly positive effects on students learning outcomes.

Mastery learning, remediation, and the GAELS period all sound great in practice, but for the last few years I have asked myself questions about the way in which we have conducted these remediation sessions. I have also spent some time informally interviewing colleagues about the strategies that they use when they conduct remediation sessions. While their responses have varied, many teachers expressed that they've never had a set way of conducting remediation, nor have they ever received instruction on best practices for doing so. Some said that remediation for them is as simple as pointing out additional resources that students can use as a review and leaving the rest up to the autonomy of the student. Few teachers have expressed a strong sense of confidence when discussing how they conduct remediation or whether they know if those strategies are working for their students. Many have certainly expressed frustration that students often don't do any better on their second attempt at the assessment. I have heard colleagues express on several occasions that re-testing simply creates more work for the teachers while the students rarely do better, thus suggesting that the whole process is a waste of time.

The goal in this project was to use four types of teaching strategies with students who were determined to be in need of remediation. The aim was to determine which of

four strategies: concept mapping, science journaling, object manipulatives, and a flipped classroom approach, produced the greatest gains from initial assessment to second attempt at the assessment. My experiences with students and colleagues in previous years lead to the creation of my focus statement: In their use as remediation strategies, how do flipped classroom, table manipulatives, concept mapping, and science journaling compare? Improvement was defined in terms of normalized gains from the initial assessment to the retake test. Students were first given the standard assessment for the unit. Students who scored less than 70% on the initial assessment were identified as being in need of remediation. Those students were then assigned to a GAELS period remediation session and were exposed to one of four remediation strategies. A different strategy was used with each unit such that each strategy was used twice during the course of the study, which covered nine total units. In addition to determining which of these strategies was most effective in terms of raising scores on retake tests, I was also interested in investigating the following sub-questions:

- How does the use of concept mapping and table manipulatives as remediation strategies affect students' ability to make connections between core ideas in a unit?
- How does the use of each remediation strategy affect student confidence?
- How do students perceive their own confidence and preparedness for assessments?

CONCEPTUAL FRAMEWORK

Mastery learning strategies have existed for quite a while in the education world. They became more common in the 1960's and consisted of two main approaches, Bloom's learning for mastery approach and Keller's personal system of instruction. In the learning for mastery approach, the teacher controls the pacing of the lessons and learning is often collaborative, whereas in the personal system of instruction approach, all learning is student paced. Of the two models, Bloom's model seems to be the most widely used and recognized model on the topic mastery learning techniques. In Bloom's model, students who fail assessments are given the opportunity to receive additional instruction on the material either in a group setting or individually (Kulik, 1990). Both approaches are similar in that students are not permitted to move on until they have mastered material. According to Guskey (2007), if students who are yet to master material are pushed to move on, minor learning gaps can become cumulative, resulting in students falling more and more behind as learning progresses. In order to prevent this, teachers should use frequent assessments to monitor learning and provide an opportunity for students who perform poorly on these assessments to re-learn the material. Assessments should serve as means of providing a detailed prescription of what additionally needs to be done in order to master the concepts or skills from a unit. Using assessments in this way "prevents minor learning difficulties from accumulating and becoming major learning problems" (Guskey, 2007, p. 13). Assessments should not be a dead end for students. They should be prescriptive. Assessments should serve to show the teacher where the learning gaps exist, and where the students need additional review.

John B. Carroll laid down much of the basis for mastery learning in 1963.

Carroll's model suggests that the actual degree of learning any given learner achieves is a function of the time needed for an individual learner to master the material compared to time spent (Block, 1976). That is, learning is not a one-size-fits-all endeavor. Each learner requires a unique level of instruction in order to master material. However, in many classrooms, time spent learning material is a function of the teacher's planning and scheduling rather than a function of the time needed by each learner in order for that learner to master the material. In many classrooms, each unit is designated a fixed amount of time which is based solely on how long it will take to cover the material and not necessarily how long it will take students to master the material. According to Guskey (2007), students might be pushed to move on too soon due to the time constraints associated with corrective activities. When presented with a choice between covering more material and spending time on corrective activities, many teachers choose to cover more material. However, Guskey claims that by simply making minor changes to instructional pacing, those issues can be resolved. For example, many teachers using mastery learning in the classroom are able to eliminate review sessions prior to assessments, "shifting that time to corrective and enrichment processes" (Guskey, 2007, p. 19). In addition to this, Guskey claims that because students in a mastery learning setting spend more time actively engaged in learning, they make more progress than those students in more traditional classrooms. In a final point regarding concerns over time constraints, Guskey noted that the effects of mastery learning strategies are essentially cumulative. This means that students are able to more quickly master succeeding units because they have mastered the previous ones. "Because mastery

learning students learn the concepts and skills from early units well, they are better prepared for later, more advanced units” (Guskey, 2007, p. 23). Guskey went on to discuss the value and importance of using mastery learning in the classroom, even when implemented with modest alterations to traditional practice, as supported by several research studies on mastery learning.

Several studies have been conducted to examine the effects of mastery learning techniques on student achievement. In a meta-analysis of 108 mastery-learning studies, it was found that all but seven studies reported that mastery programs had positive effects on examinations given at the end of instruction (Kulik, 1990). The analysis found that “the average student in a mastery learning class performed at the 70th percentile [...] whereas the average student in a class taught without a mastery requirement performed at the 50th percentile” (Kulik, 1990, p. 271). Results of mastery programs are not limited to test scores. Factors such as student confidence, involvement and participation, confidence, and attitudes towards learning are also all positively affected by mastery learning programs (Guskey, 2007). In one long-term study on mastery learning, 18 years of data from over 7,000 high schools was collected. The results showed that mastery learning strategies had positive effects on students’ GPA, attitudes towards learning, and test scores (Whiting, 1995). In addition to this, Whiting claimed that mastery learning techniques helped students identify their learning style, resulting in more efficient use of study time. Results of this study showed that 97% of students rated their level of learning at nine or ten on a ten point scale, and 98% of students indicated that they would like other classes taught with mastery learning. The strategy for mastery learning used in the Whiting study was based on the Block/Bloom model for mastery learning.

Block (1976) discussed Bloom's ideas on mastery learning and suggested that in order to be effective, students in mastery programs should be provided with feedback based on assessments for learning, and then provided with differential instruction that meets individualized learning needs. Feedback alone does not help students in need of remediation overcome the initial obstacles they face when attempting the first assessment. The teacher in a mastery-learning environment must carefully select activities that address the specific misconceptions held by students. Guskey, 2007 notes,

Feedback does little to help students improve their learning. Significant improvement requires feedback to be paired with correctives: activities that offer guidance and direction to students on how to remedy their learning problems. Because of individual differences among students, no single method of instruction works best for all. To help every student learn well, therefore, teachers must differentiate their instruction, both in the initial teaching and especially through the corrective activities. (p. 10)

Several techniques have been demonstrated as effective methods to aid in mastery learning. In order to meet the needs of diverse learners, these techniques should be different from those that were initially used when the material was initially taught. Each student learns differently, and one can assume that if a student did not master the material on his or her first attempt, the first method of instruction was ineffective for that student.

To be effective, correctives must be qualitatively different from the initial teaching. They should offer students alternative approaches and additional time to learn. The best correctives present concepts and involve students in learning differently than the initial instruction. (Guskey, 2007, p. 16)

Various teaching strategies exist that can be used for the purpose of conducting remediation and working towards mastery learning. These include concept mapping and other meta-cognitive strategies (Novak, 1990; Ritchie, 2000), a flipped classroom approach (Gilboy, 2014), science journaling, and object manipulatives (Ritchie, 2000), to

name a few. In some cases, remediation techniques can be as simple as providing students with additional resources to review, personalized to meet the student's individualized learning needs, that is, the concepts that the students did not master on their first attempt. It is up to the teacher to decide which corrective is best suited to the needs of the learner based on the specific concepts that were missed.

Teachers pair specific corrective activities for use in correcting learning difficulties with each formative assessment. The correctives typically are matched to each item or set of prompts within the assessment so that students need work on only those concepts or skills not yet mastered. In other words, the correctives are individualized. (Guskey, 2007, p. 12)

Correctives need not be complicated. Some correctives can be as simple as pointing out sources of information on a particular concept, such as page numbers in the textbook or workbook, where that concept is discussed. The use of correctives might simply mean providing students with additional resources for learning, such as videos. Use of correctives could also mean putting students in groups for review or providing additional study materials. There are a number of diverse ways to address the needs of learners who are in need of additional learning opportunities (Guskey, 2007).

In addition to using correctives to simply review material that students did not yet master and reinforce learning objectives, it may be useful to address other issues pertaining to why students may not have learned the material on their first attempt beyond assuming that they simply didn't understand the material. Factors such as student anxiety may have an effect on student learning (Lazarowitz, 1996). Students may also lack the study skills necessary in order to properly prepare for assessments (Gettinger, 2002). Learning how to learn and how to organize new information may be the key to successful remediation, or even preventing the students from ending up needing

remediation in the first place. Strategies such as concept mapping and table manipulatives may be particularly useful for this purpose (Ritchie, 2000).

A study of 51 biology students found that concept mapping enhanced student learning and decreased student anxiety. Jegede (1990) stated,

Anxiety, a situation of foreboding, which has been found to affect learning, is certainly one of the pressures which exert considerable influence on learners' intellectual competence and performance. It may well be that the regular use of the metacognitive strategy makes the students feel very comfortable and stabilizes their emotional state when working within intricate and interconnected systems of thought. This may explain why concept mapping lowers anxiety levels towards the learning of biological concepts. (p. 957)

Concept mapping involves metacognition, which is the process of thinking about one's own learning and reflecting on one's thought process. This process may prove useful when used with students who feel overwhelmed when presented with a set of complex ideas and who lack the skills necessary to organize those ideas. Due to this, concept mapping may prove to be an effective remediation strategy (Jegede, 1990).

Remediation may also include the incorporation of a flipped classroom approach. Lecture is hard to avoid in situations when students hold very little prior knowledge in regards to the subject matter. However, lecture alone has its challenges, which include keeping students engaged and involved during lecture. "Research on lectures has demonstrated that a student's attention declines after the first 10 minutes of class" (Gilboy, 2015, p. 1). While lecture is necessary in some situations, it is the construction and reconstruction of knowledge that helps students truly make sense of information. Gilboy (2015) suggests that a flipped classroom approach could prove an effective strategy for student learning. The flipped classroom approach frees up in-class remediation time for more engaging active-learning opportunities, while also providing a

way to re-disseminate missed information to students. “The construction and reconstruction of knowledge in which students engage is best done through the use of active learning strategies (e.g., problem-based learning, simulation, think-pair-share)” (Gilboy, 2015, p. 1). A combined strategy of flipped classroom followed by active learning during remediation sessions in the classroom using techniques such as concept mapping, group work, table manipulatives and journaling could prove to be a comprehensive and effective remediation strategy and ultimately lead to mastery of the material.

There are a number of remediation techniques that are promising for providing a more enriching and effective way of providing remediation and mastery learning for students. Mastery learning is beneficial for students because it prevents students from accumulating large learning gaps. So long as remediation is done mindfully, using techniques that have been previously deemed effective learning strategies, students should be able to attain high levels of mastery.

METHODOLOGY

Treatment

This project took place over the course of nine instructional units spanning approximately seven months. Units covered included the chemistry of life, cell transport, photosynthesis, cellular respiration, cell division (mitosis and meiosis), genetics, evolution, and classification. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A). At the conclusion of each unit, students in college-preparatory level biology were given a chapter assessment that

consisted of a combination of multiple choice, fill-in-the-blank, and short answer questions (Appendix B). The various chapter assessments served as a pre-test during this study, as they were the students' first attempt at mastery. After giving the test, students in need of remediation were identified. Any student who scored less than 70% on the chapter assessment was assigned to a remediation session during our school GAELS period, a mid-day period designed for both remediation and enrichment activities. Due to the nature of how students were assigned, a slightly different group of students attended each of the sessions. Students who completed remediation were allowed a chance to retake the chapter assessment in an attempt to improve their grades, as per school policy. While their maximum score on the retake could not exceed 70% in the grade book due to school policy, for purposes of this research, students' total score on the retake was used for data analysis. Scores from the students' first attempt at the chapter assessment, and retake test scores post-remediation were compared using normalized gains. The retake tests consisted of ten open-ended essay-style questions (Appendix C). The number of students assigned to remediation varied by unit but ranged from approximately ten to twenty-five students.

Students who were assigned to remediation for the unit were exposed to one of four instructional strategies designed to serve as remediation techniques. One strategy was used with each unit, so over the course of eight units, each strategy was used twice. During the first unit, none of the experimental strategies were used so that the first unit could serve as a means of comparison between traditional remediation techniques and the new strategies. During the first unit, students in remediation were exposed to the

traditional method used for remediation in my classroom, which involved simply going over the review guide again, re-lecturing, and answering students' questions.

Table manipulatives were used as a remediation strategy for the units on cellular respiration and genetics. Concept mapping was used for the units on cell transport and photosynthesis. Flipped classroom was used for the mitosis and classification units. Finally, science journaling was used for the meiosis and evolution units. The strategies used, along with the units for which they were used, are listed in Table 1.

Table 1
Instructional Units, Essential Learning Outcomes, and Remediation Techniques

Unit	Essential Learning Outcomes of Each Unit in terms of SWBAT (Students Will be Able To):	Instructional Strategy for Remediation
Chemistry of Life	<ul style="list-style-type: none"> • Identify parts of an atom • Identify reactants and products of chemical reactions • Analyze the polar nature of water and make connections between its polarity and ability to act as a critical molecule for life • Identify the function and structures for each of the four macromolecules of life. • Differentiate between monomer and polymer • Explain the importance of enzymes in biochemical reactions • Analyze and interpret data to determine the effect of enzymes on chemical reactions and determine under which environmental conditions they best function 	Traditional review consisting of lecture, going over a review guide, and answering questions.
Cell Transport (osmosis, cell membrane, diffusion)	<ul style="list-style-type: none"> • Predict the direction of water movement when a cell is placed into solutions of varying tonicity • Create a model to represent the structure and function of the cell membrane • Differentiate between simple diffusion, facilitated diffusion, and active transport • Create an analogy to explain the process of active vs. passive transport 	Concept mapping
Photosynthesis	<ul style="list-style-type: none"> • Identify the reactants and products of photosynthesis • Describe the two phases of photosynthesis (light dependent and light independent) and explain which reactants and products are involved in each stage • Differentiate between the roles water and carbon dioxide play in photosynthesis • Create an analogy to explain the role of ATP as energy for the cell • Draw an ATP molecule and label each part • Map the flow of energy throughout the process of photosynthesis; identify sunlight, ATP, and sugars as various forms of energy 	Concept mapping

Cellular Respiration	<ul style="list-style-type: none"> • Identify the reactants and products of cellular respiration • Compare and contrast cellular respiration and photosynthesis • List the three phases of cellular respiration and identify reactants and products involved in each stage • Differentiate between respiration and fermentation 	Table Manipulatives
Mitosis	<ul style="list-style-type: none"> • Draw and label the cell cycle • Explain the processes involved in each stage of the cell cycle • Differentiate between sister chromatids and homologous chromosomes • Create a model to represent the process of cell division 	Flipped Classroom
Meiosis	<ul style="list-style-type: none"> • Differentiate between mitosis and meiosis • Differentiate between meiosis I and II • Explain the differences between the purpose of mitosis vs. the purpose of meiosis and the types of cells they create • Define “haploid” and “diploid” 	Science Journaling
Genetics	<ul style="list-style-type: none"> • Determine probability of outcomes of genetic crosses • Differentiate between various inheritance patterns • Interpret a pedigree • Differentiate between autosomal and sex-linked traits 	Table Manipulatives
Evolution	<ul style="list-style-type: none"> • Describe how evolution is driven by natural selection • Differentiate between various patterns of evolution (convergent evolution, co-evolution, adaptive radiation) • Describe patterns of evolution within populations 	Science Journaling
Classification	<ul style="list-style-type: none"> • Differentiate between traditional classification schemes and modern systematics • Create a dichotomous key • Interpret a cladogram • Describe the relationship between the evolutionary history of a species and its relatedness to other species 	Flipped Classroom

For the chemistry of life unit remediation, students who attended the GAELS period were exposed to the standard remediation technique as a non-treatment. During this remediation session, students were asked to take out their review guides and we spent the GAELS period going over their chapter review questions. These questions had been previously assigned prior to the chapter assessment. Chapter concepts were re-explained in a lecture format and I utilized the whiteboard to draw diagrams. Students asked specific questions from the review guide and were reminded of the main themes from the chapter. I reminded students of a few topics that they would need to focus on studying for

the retake exam, and students were asked to use their review guides, their book, and notes from the GAELS period review to study for the retake.

For the unit over cell transport, concept mapping was utilized as a remediation strategy. Students completed a concept map using an app on their iPads called Inspiration. Students were given a list of terms that were required to be used somewhere on the concept map. Students were then given direct instruction on how to create a concept map. The creation of a concept map was demonstrated on the front whiteboard. Students then spent the remainder of the GAELS period creating concept maps. I walked around the room, from student to student, checking progress. If I noticed that a student was struggling or rushing, I redirected the student or helped them create a few bubbles on their concept map to get them started. If the maps were not finished during the GAELS period, students were asked to finish them as homework prior to taking the retake test. I utilized complete maps as a sort of ‘ticket’ to retake the exam. If maps were incomplete, missing terms, or poorly done, students could not retake the chapter assessment.

For the next unit, photosynthesis, concept mapping was again used as the primary remediation strategy. Students were provided with a list of chapter terms. Terms included things like: light independent reactions, sunlight, water, ATP, and NADPH, among others. Students were given a brief introduction on how to create a concept map and then asked to create a map using the list of terms provided. Students were allowed to finish the concept map at home if they had not finished by the end of the remediation period. A complete map was required in order to retake the chapter assessment.

Table manipulatives were utilized as the remediation strategy for the cellular respiration unit. Students were asked to complete two sets of table manipulatives, each

contained within their own bag. The first bag contained a large picture of a chloroplast, several arrows, and terms such as *oxygen*, *ATP*, and *CO₂*. Students were asked to arrange the arrows and terms in and around the mitochondria in a way that represented the process of cellular respiration. The second bag contained a large Venn diagram and several terms. Students were asked to place the terms *anaerobic respiration* and *aerobic respiration* on either side of the diagram and use the remaining terms, which included things such as, *oxygen is a reactant* and *ATP is produced*, and place them either on the side exclusively for aerobic, exclusively for anaerobic, or in the middle of the diagram if the term applied to both categories.

For the next unit, mitosis, a flipped classroom approach was utilized as the primary remediation strategy. Students who were assigned to remediation were asked to watch several instructional videos and tutorials on their own at home. Completion of the at-home portion of the remediation was tracked using an app called EdPuzzle. The videos were assigned on the app and students were required to log in in order to view the videos. The app tracked how much time was spent watching each video as well as the date and time accessed. The app allowed me to verify that the students did indeed watch the videos prior to coming to remediation. EdPuzzle also allowed for the insertion of comprehension questions throughout the videos, which students were required to answer before they could continue watching the videos to completion. The questions consisted of multiple choice and open-ended responses. The assigned videos included one from Paul Anderson's Bozeman Science YouTube channel as well as a video from the Amoeba Sisters YouTube channel.

When students came to the in-class portion of the flipped classroom remediation during GAELS period, they were placed into groups of three to four and given a large piece of paper at the center of their group table. I provided a list of questions and topics that I wanted each group to discuss and draw. I walked around the room and monitored group progress. Students were not allowed to leave the GAELS period until they had discussed each topic in detail with the group.

The flipped classroom approach was again used with the classification unit. Students were asked to watch three review videos as homework prior to coming to the remediation session. When students came to the GAELS period, they were asked to get into groups of three to four and given a large piece of paper and sharpies. Students within the groups were asked to discuss several chapter topics, which were listed on the whiteboard. I walked around the room monitoring student progress and asked students to summarize their group discussions and show me what they had drawn.

The last remediation strategy, science journaling, was used with the meiosis and evolution units. Students in need of remediation were asked to sit with a partner during the remediation period and take out their laboratory composition notebooks. These notebooks are usually used to record lab data and observations during class labs. For the remediation, students created an interactive notebook page on the chapter material. The interactive notebook pages began with a personal reflection of what students felt most confused about from the chapter. The pages also included cut-outs that were colored, ordered, and glued into the notebook. In addition to this, the journal entries included diagrams, writing prompts, and concluded with writing down a muddiest point from the

chapter, that is, the things that each student felt that they least understood and still needed help with prior to attempting a retake.

Data Collection

To assess student confidence with the chapter material prior to remediation, students were given the Student Confidence Survey (Appendix D). Students were asked to rank their level of confidence with the chapter material on a scale ranging from one to five with one being very non-confident and five being very confident. Students then spent the remainder of the remediation period in review using one of the four remediation strategies. After the remediation session, students were asked to use the Student Confidence Survey to rank their level of confidence with the chapter material post-remediation.

In order to assess student perceptions of their learning styles, learning struggles, and study techniques, students were also given the Student Perceptions of Learning survey, on which they were asked questions relating to their perceived learning preferences (Appendix E). Students were asked if they agreed or disagreed with various statements regarding their perceptions of their own learning styles and learning struggles. These responses were ranked from one to five with one being strongly disagree and five being strongly agree.

Students' perceptions of the interrelatedness of chapter material and concepts were assessed with the Student Perceptions of Learning survey. Responses to these questions were assessed on the same one to five scale and the percentage of students who reported seeing the chapter material as connected/related to other chapters was compared to their average normalized gains as a group from pre to post-test.

The Student Perceptions of Learning survey also asked students to rank their own perceptions of how they learn, whether from lecture or hands-on activities. The percentage of students who identified during each remediation session as learning best from lecture versus hands-on activities was compared to normalized gains from pre to post-test for the specific remediation strategy for the unit.

Finally, students were asked to come in sometime after the remediation session for a Post-treatment Interview consisting of nine questions relating to how students felt about their readiness to take the first test versus the retake, and how they felt about the use of the given remediation strategy as a means to help them prepare for a second attempt at the chapter assessment (Appendix F). Student responses were qualitatively assessed and compared to their responses to survey questions and how they performed on the retake test.

Students who completed all assigned remediation tasks were given a pass to retake the chapter test. The retake tests consisted of ten open-ended, essay-style questions. Each question focused on a specific essential learning outcome from the chapter. Students could earn partial credit on these types of questions and were encouraged to write as much as necessary to explain each concept (Appendix C). The scores from pre to post-test were analyzed using normalized gains. An average normalized gain was calculated for each unit and each strategy. Following this, a two sample two-tailed t-test was used to determine if the change in scores from pre to post-test was considered significant, with a confidence limit of 95%.

Table 2
Data Triangulation Matrix

Research Questions	Data Sources
<p><i>Primary Question:</i> In their use as remediation strategies, how do flipped classroom, table manipulatives, concept mapping, and science journaling compare?</p>	<ul style="list-style-type: none"> • Pre and post-test scores and normalized gains • Two sample two-tailed t-test • Student Interviews • Pre and post-test Student Confidence Survey
<p>How does each strategy affect student confidence?</p>	<ul style="list-style-type: none"> • Student confidence survey • Student Interviews
<p>How do students perceive their own preparation and readiness for assessments?</p>	<ul style="list-style-type: none"> • Student Perceptions of Learning Style Survey • Student Interviews

DATA ANALYSIS

The results of the standard chapter-two test remediation, used as a non-treatment, showed an average normalized gain of -2.4% ($N=17$). Forty-one percent of students who took the retake exam were able to improve their scores. The highest normalized gain achieved by a student was 38%. The mean score on the pre-test was 56.5% while the mean score on the post-test was 55.6%. The median on the pre-test was 57% while the median on the post-test was 55%. The post-test data showed a greater overall range of scores than the pre-test data (Figure 1).

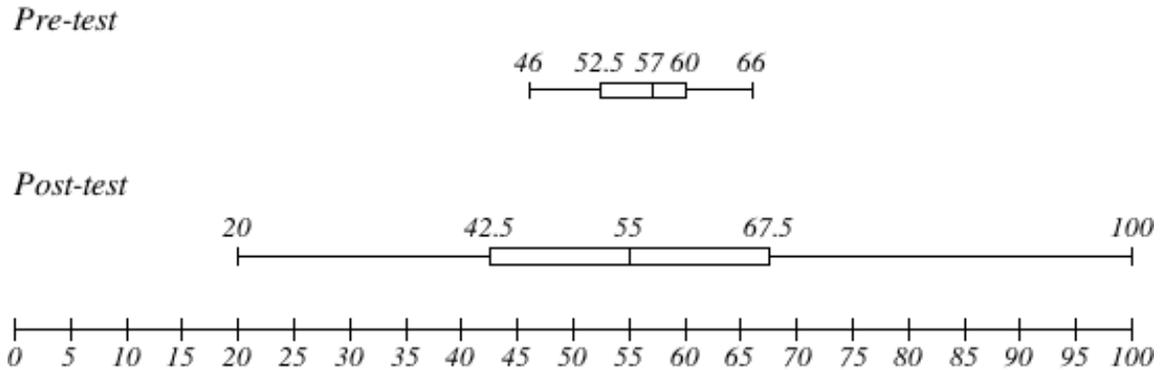


Figure 1. Pre and post-test data for chemistry of life unit, ($N=17$).

A two sample unpaired two-tailed t-test was used to determine if these data were significant. The results of this test gave a p-value of .87, which was well above the confidence limit of .05. Therefore, the change in scores from pre to post-test was not considered significant.

The results of the cell transport remediation, utilizing concept mapping as the experimental remediation strategy, showed an average normalized gain of 24% from pre to post-test. The mean score on the pre-test was 49.3% while the mean score on the post-test was 62.3%. The median from pre to post-test shifted from 52.5% to 63.8%. Eighty percent of students were able to improve their scores from pre to post-test. The post-test results showed a greater distribution of scores overall, with the majority of the increased distribution falling between the median, third quartile, and maximum score. The upper quartile shifted from 57% to 70.6% from pre to post-test ($N=10$)(Figure 2).

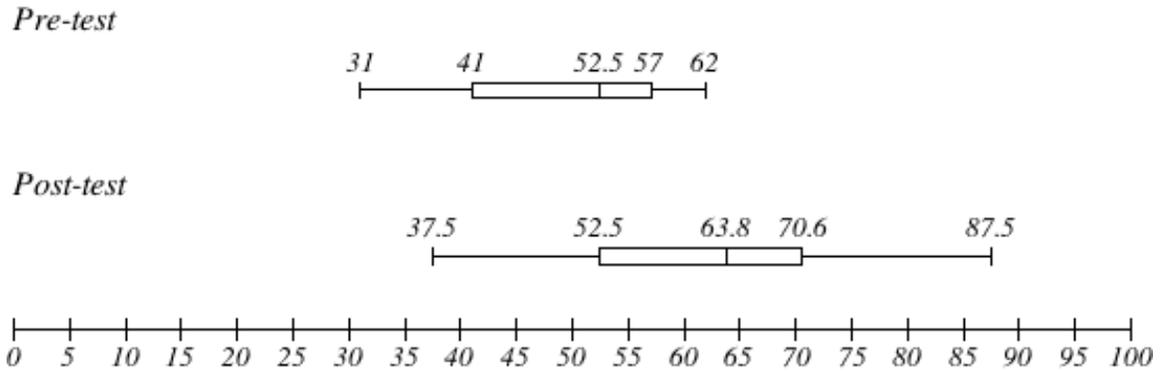


Figure 2. Pre and post-test data for cell transport unit, (N=10).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. The test yielded a p-value of .044, which was below the confidence limit of .05. Therefore, the change in these data from pre to post-test can be considered significant with a confidence level of 95%.

When asked on the Student Perceptions of Learning survey if they felt they learn best from hands-on activities such as labs and projects, the average reported rating was 4.0, which correlated to agree. When asked to rate their level of agreement or disagreement with the prompt, lecture helps me understand the material, students responded with an average rating of 4.3 which correlated with falling between agree and strongly agree (N=6).

When asked to rate their own level of confidence with the unit material on the Student Confidence Survey, 66% of students reported an increase of confidence with the unit material after the remediation (N=6). Thirty-three percent of students ranked their confidence with the unit material the same from pre to post remediation. The average ranking for self-reported student confidence pre-remediation was 2.7, which correlated

with falling between somewhat not confident and neutral. The average student-reported confidence level post-remediation was a 4, which correlated to somewhat confident (Figure 3).

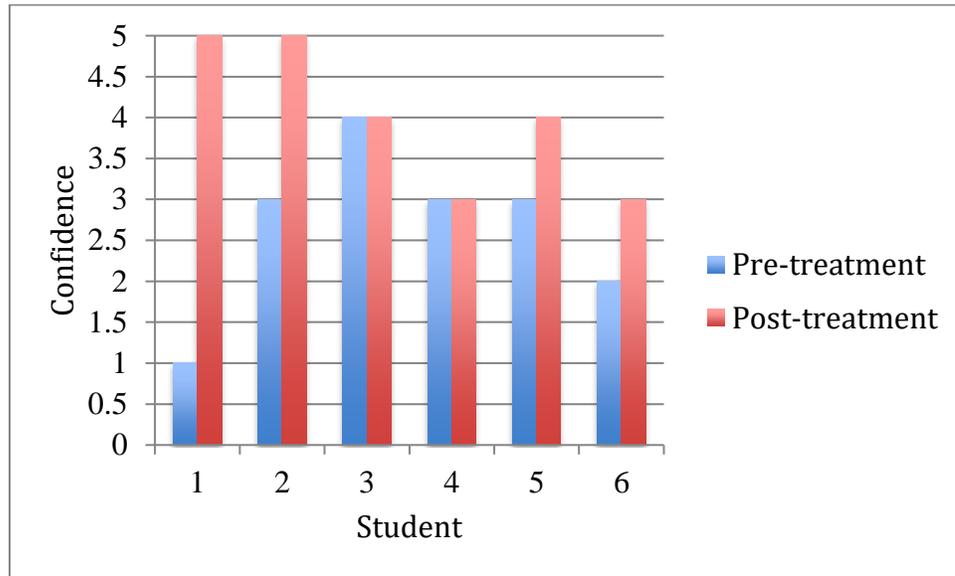


Figure 3. Student-reported confidence from pre-remediation to post-remediation for cell transport unit, ($n=6$).

When asked during a post-remediation interview if they felt prepared for the first attempt at the chapter assessment, 40% of students stated that they felt they focused too much on memorizing the material, which they went on to say didn't prepare them for the assessment in hindsight ($n=5$). Two other students indicated that their main method of studying involved attempting to memorize questions from an in-class review game, or making and memorizing a quizlet. When asked what they felt may have helped them better prepare for the assessment, one student said, "I guess, focus more on the broad questions of the chapter, not just the small ones."

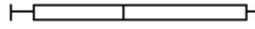
When asked on the Student Perceptions of Learning Survey to respond to the statement, The concepts we learn throughout one chapter are related/interconnected to

each other, students in this group responded with an average rating of 4.3, which correlated to falling slightly above agree. When this same group of students was asked to respond to the statement, Seeing how different concepts throughout a chapter relate to one another is challenging for me, students responded with an average rating of 2.8, which correlates to falling slightly below neutral.

When asked during the post-remediation interview if they felt what was done during GAELS period was helpful, 100% of students said that it was helpful, with several students mentioning that it helped them make connections between chapter concepts. One student said, “putting the terms together and seeing that they connect in some way really helped a lot.”

The results of the photosynthesis remediation, which also utilized concept mapping as the remediation strategy, showed a negative average normalized gain. On average, students dropped 16%, when normalized for possible points that they could have gained based on their pre-test score ($N=6$). Only one of the six students, or, 16% of students was able to raise their score from pre to post assessment. One student’s score remained exactly the same, and the remaining 67% of students performed lower on the retake than on their first attempt at the chapter assessment. The mean score on the pre-test was 50.7% while the mean score on the post-test was 43.8%. The median from pre to post-test shifted from 50% to 45% (Figure 4).

Pre-test



Post-test

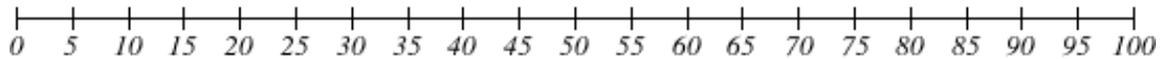
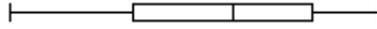


Figure 4. Pre and post-test data for photosynthesis unit, ($N=10$).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. The test yielded a p-value of .26, which was above the confidence limit of .05. Therefore, the change in these data from pre to post-test was not considered significant.

When asked to rate their own level of confidence with the unit material both pre and post remediation, 100% of students reported an increase of confidence with the unit material after the remediation ($N=4$). The average ranking for self-reported student confidence pre-remediation was a 2.5, which correlated with falling between somewhat not confident and neutral. The average student-reported confidence level post-remediation was a 4.5, which correlated to falling between somewhat confident and very confident (Figure 5).

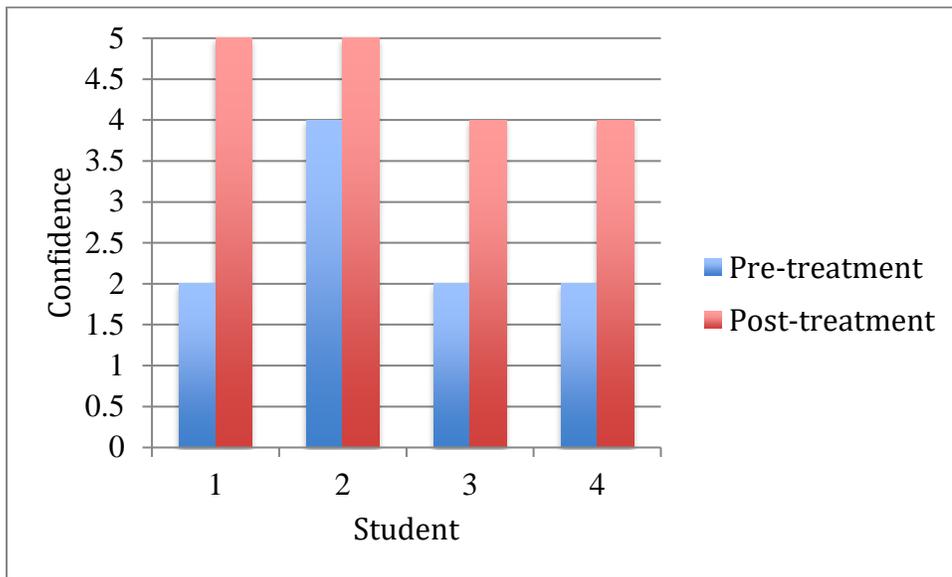


Figure 5. Student-reported confidence from pre-remediation to post-remediation for photosynthesis unit, ($n=4$).

When asked during a post-remediation interview if they felt that the remediation strategy was useful, 75% of students said that concept mapping was helpful ($N=4$). Two of the students mentioned during their interview that they identify as visual learners, and went on to say that having all the concepts laid out in front of them, like a diagram or picture, was helpful. The student who stated that the concept mapping wasn't very useful for her, went on to say that she thinks she learns best from listening rather than from hands-on activities. She also stated that she doesn't have a problem listening and paying attention when things are being verbally explained. In regards to the concept mapping, she stated, "it was kinda hard, because it just seemed like we were just trying to take everything and shove it all into one thing." She went on to say that she wished we played a review game instead. When asked what I as the teacher could have done differently to help her prepare, she said that she wished I directly explained the concepts again while drawing diagrams on the board.

When asked on the Student Perceptions of Learning survey if they felt they learn best from hands-on activities such as labs and projects, the average reported rating was 3.5, which correlated to falling between neutral and somewhat agree. When asked to rate their level of agreement or disagreement with the prompt, lecture helps me understand the material, students responded with an average rating of 4.5 which correlated with falling between agree and strongly agree ($N=4$).

The results of the cellular respiration test remediation, which utilized object table manipulatives as the remediation strategy, showed an average normalized gain from pre-test to post-test of 20% ($N=18$). The mean score on the pre-test was 56.7% while the mean score on the post-test was 64.2%. The median score shifted from 60% to 70% from pre to post-test. The third quartile shifted from 67% to 80% from pre to post-test (Figure 6).

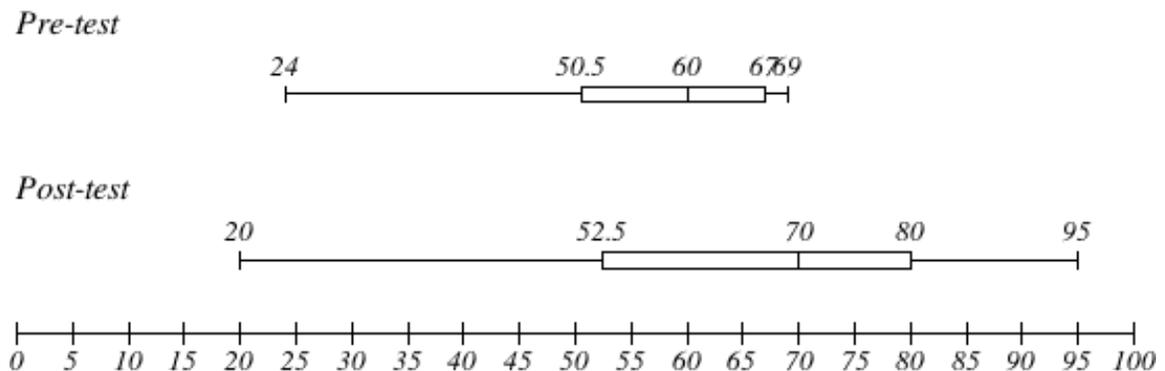


Figure 6. Pre and post-test data for cellular respiration unit, ($N=18$).

An unpaired two-sample t-test was used to determine if these data were significant. A p-value of .098 was calculated which was above the confidence limit of .05 for a confidence level of 95%. Therefore, the change from pre to post-test for these data was not considered significant.

Student self-assessment of confidence shifted from an average score of 1.9, which correlated to falling slightly below somewhat non-confident, to an average score of 3.5, which correlated with falling between neutral or somewhat confident. Overall, 87.5% of students reported that their confidence regarding chapter material had increased from pre to post-treatment ($N=8$) (Figure 7).

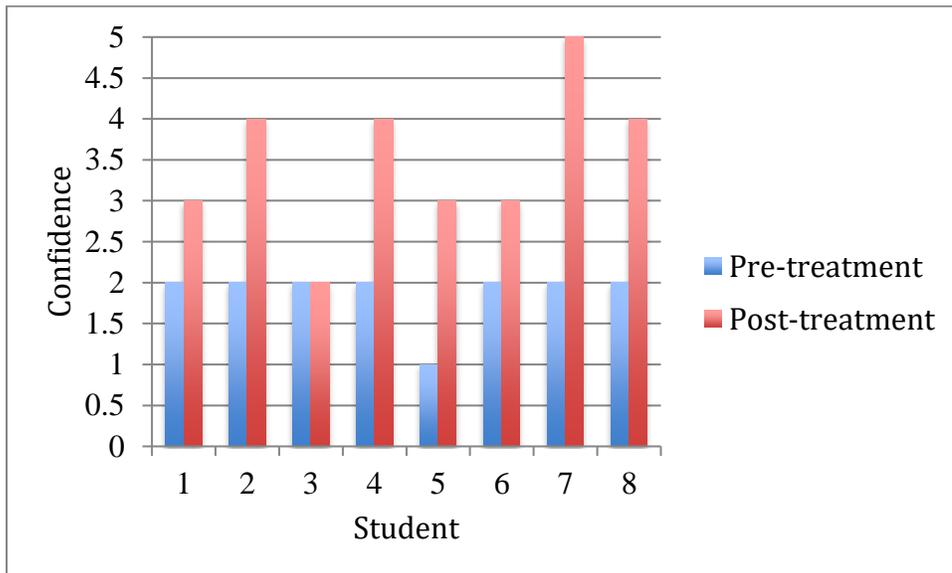


Figure 7. Student-reported confidence from pre-remediation to post-remediation for the cellular respiration unit, ($n=8$).

When asked on the Student Perceptions of Learning survey if they felt they learn best from hands-on activities such as labs and projects, 62.5% of students responded that they strongly agreed with this statement and 25% responded that they agreed with this statement ($N=8$). The average rating for this question was 4.5, which correlated to falling between agree and strongly agree. When asked during an interview if they felt they learn best from actively working on an assignment, or from listening to a lecture, one student responded, “I think it’s a mix, if it’s just hearing, I usually don’t get the whole thing, I miss parts, but if it’s just hands-on, I don’t always get it without having it explained at

least a little.” Another student responded, “with hands-on, we’re usually working in groups, so sometimes you get this situation where only one person in the group understands it, and the rest of the group is just following the person who understands and you don't understand at all.”

When these students were asked to rank their level of agreement with the statement, Lecture helps me understand the material, 37.5% of the students agreed with this statement and 50% indicated that they were neutral. The average rating for this question was a 3, which correlated to neutral. When asked during an interview if they felt they could pay attention during lecture, one student said, “I really want to listen, but all of a sudden I’ll find myself doodling on my paper or daydreaming about what I want to have for dinner. All of a sudden I’ll look up and there’s like, this whole molecule on the board with arrows and I have no idea what I’m looking at.”

When asked during an interview if they felt the table manipulatives were helpful as a strategy to re-learn the material, one student said, “yes, it was helpful, because I could listen to my friend explain it, and I could do it hands-on and for me it helped a lot.” One student said, “it (the manipulatives) helped me see what I knew already and what I needed to know more.” Several students told me that they would have appreciated more one-on-one time with the teacher and that the number of students who attended this particular remediation session made using table manipulatives more difficult. One student indicated that she wished we could have done a mix of lecture and hands-on activities during the remediation because she still had questions on the chapter review guide that she wanted me to explain. That same student said, “I don’t feel that much more confident after doing the remediation today because honestly I didn’t study for the test the first

time, so not only did I not know what I was doing on the test, but I also didn't have any idea what I was doing today. I think I wasn't ready to do either." When asked if there's anything else they'd like me to know, several students said it would be very helpful to have one-on-one time with me as a teacher to go over the material rather than a large group remediation session. Another student indicated that she struggles with seeing the connection between what's on the study guide for a test and what's actually on the test and that she'd like more help figuring out what to study.

As a group, when asked on the Student Perceptions of Learning Survey if they felt learning the vocabulary for the chapter would help them do well on the test, 50% of students said they agreed or strongly agreed with this statement, 25% were neutral, and 25% stated that they disagreed with this statement. The students who indicated that they strongly agreed with this statement also ranked the next statement which stated, seeing how different concepts throughout a chapter relate to one another is challenging for me, 25% higher than the students who disagreed that learning the vocabulary was a good way to prepare for the test.

When asked if tests made them feel anxious, all but one student said that tests gave them at least some anxiety. One student responded, "absolutely, yes." A few students indicated that whether or not they felt anxious when taking tests depended on how prepared they felt were for the test.

The results of mitosis remediation, which utilized a flipped classroom approach as the remediation strategy, showed an average normalized gain of 29% from pre to post-test. The mean score on the pre-test was 57.3% while the mean score on the post-test was 69.3% ($N=7$). The median shifted from 56% to 70% from pre to post-test. On the pre-test,

the maximum value fell directly at the end of the third quartile at 65%. For the post-test data, the minimum value fell directly at the beginning of the first quartile and the maximum value fell directly at the end of the third quartile (Figure 8).

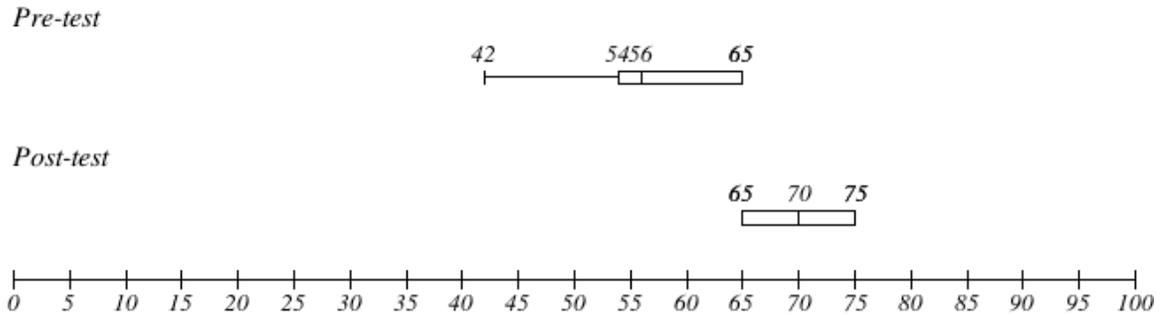


Figure 8. Pre and post-test data for mitosis unit, (N=7).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. A p-value of .0052 was calculated which was below the confidence limit of .05 for a confidence level of 95%. Therefore, the change from pre to post-test for these data was considered significant.

Student self-assessment of confidence shifted from an average score of 2.3, which correlated to falling between somewhat non-confident and neutral to an average score of 4.3, which correlated with falling between somewhat confident and very confident. Overall, 83.3% of students reported that their confidence regarding the chapter material had increased from pre to post-treatment (N=6). One student ranked their confidence with the chapter material the same from pre to post-treatment (Figure 9).

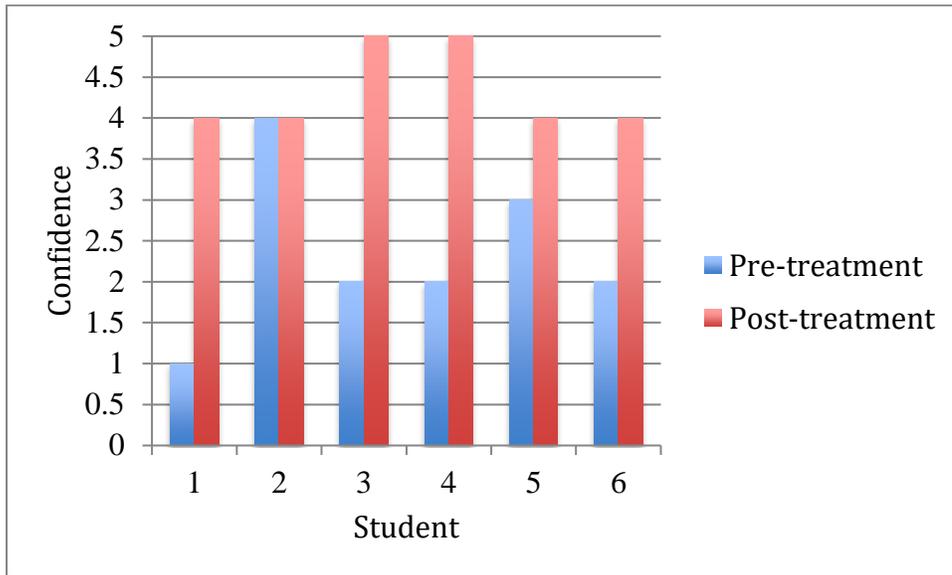


Figure 9. Student-reported confidence from pre-remediation to post-remediation for mitosis unit, ($n=6$).

When asked on the Student Perceptions of Learning survey to rank their level of agreement with the prompt, I feel that I learn best from hands-on activities like labs and projects, the average response was a 4.7, which correlated to falling between agree and strongly agree. When asked to respond to rank their level of agreement with the prompt, Lecture helps me understand the material, the average ranking was a 3.3, which fell between neutral and somewhat agree.

When asked during a post-treatment interview if students felt that they were able to pay attention during in-class lectures, one student responded, “no, because there are always distractions during class.” Another student responded “yes” to the same question, but noted that he didn’t feel that he got a lot out of lectures regardless of being able to pay attention. Another student responded to this prompt by saying, “I just can’t focus if I have to sit there listening to someone talk. There are some interesting parts to lectures, but sometimes I get bored.” When this same student was asked if the remediation

strategies were helpful, she exclusively discussed the group work portion of the remediation as being helpful, but noted that she has a hard time sitting down and watching videos. When another student was asked if he felt he could pay attention during lectures he responded, “half the time”. This student then went on to say that the review videos were more helpful to him than the group work during the remediation. This student said the he was able to rewind videos if he missed a part, which was helpful.

The results of the meiosis remediation, which utilized science journaling as the remediation strategy, showed an average normalized gain of 29% from pre to post-test. Ninety-one percent of students were able to raise their score on the retake test (N=11). The mean score shifted from 53% on the pre-test to 67% on the post-test. The median shifted from 57% to 67.5% from pre to post-test. The overall range of scores increased, with the maximum score moving from 64% to 87.5% (Figure 10).

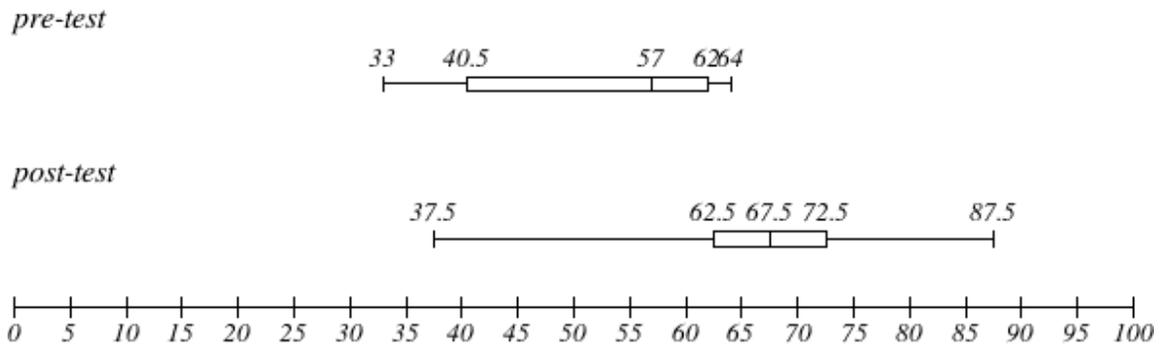


Figure 10. Pre and post-test data for meiosis unit, (N=11).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. A p-value of .025 was calculated which was below the confidence limit of .05 for a confidence level of 95%. Therefore, the change from pre to post-test for these data was considered significant.

When asked on the Student Perceptions of Learning Survey to respond to the statement, I feel that I learn best from hands-on activities like labs and projects, the average student response was 4.8, which correlated with falling between strongly agree and agree. When asked on that same survey to respond to the statement, Lecture helps me understand the material, the average rating was 3.4.

During a post-remediation interview, when asked how they felt they learn best, several students responded that a combination of strategies is most helpful to them. One student said, “During lectures, if they get too long, I can’t pay attention and lose focus.” Another student said, “I need a combination of hearing it and then actually working with it.” When one student was asked if they felt the science journaling was helpful, they said, “being able to see the processes helped, and writing down the list of things I was most confused about helped me realize what I needed to study.” When asked if they felt science journaling was helpful for reviewing the material, all students interviewed said that it was helpful (N=6). When asked during the interview what they felt could have been done differently during the remediation period in addition to or instead of science journaling, a common theme among all those interviewed included that they wished for more basic quizzing. Several students said that they wished we had made flashcards, or played a Q&A type review game. A number of students responded along the lines of “I think it would’ve been more helpful if you had just quizzed us with flashcards”.

When asked on the Student Perceptions of Learning survey to rate their confidence level both pre and post-treatment, student-reported confidence shifted from 2.5, which correlated to falling between somewhat not-confident and neutral, to 4.1, which was slightly above a rating of confident. Eighty-eight percent of students reported

an increase in confidence with the chapter material from pre to post-treatment (Figure 11).

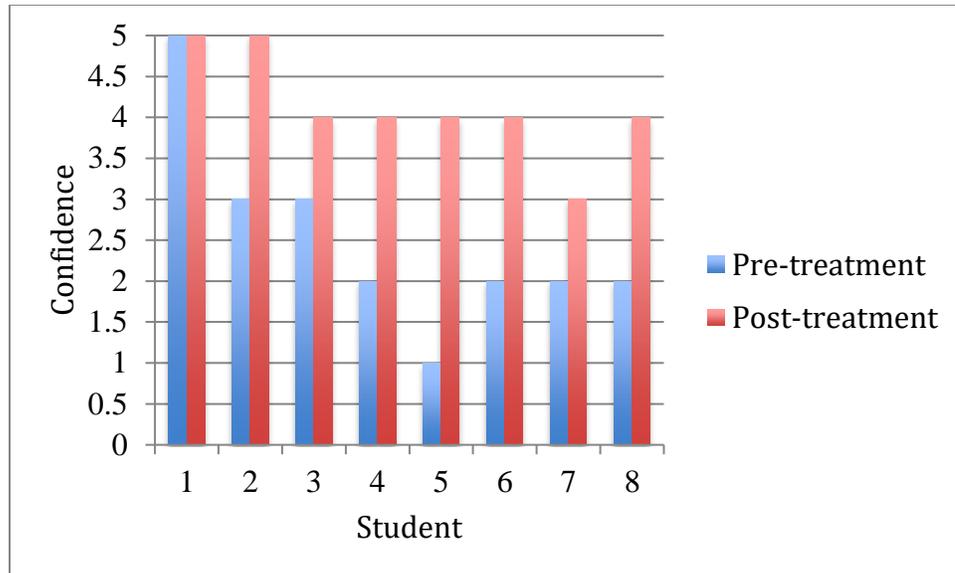


Figure 11. Student reported confidence for meiosis unit, ($n=8$).

The results of the genetics unit remediation, which utilized table manipulatives as the remediation strategy, showed a negative average normalized gain of 3% from pre to post-test. The mean score on the pre-test was 51% while the mean score on the post-test was 49%. Fifty percent of the students who completed the remediation and took the retake test were able to raise their score on the retake test. The median score shifted from 55% to 46% from pre to post-test. The maximum score increased from 66% to 95% ($N=16$) (Figure 12).

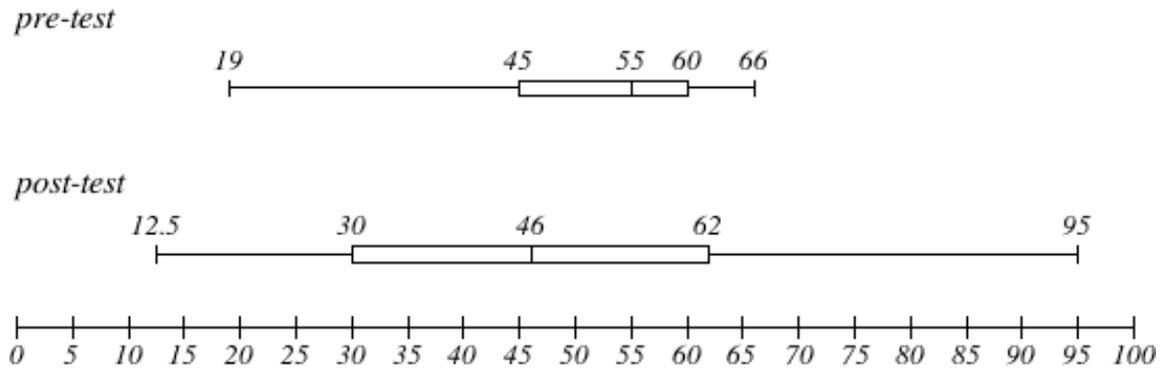


Figure 12. Pre and post-test data for genetics unit, (N=16).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. A p-value of .77 was calculated which was well above the confidence limit of .05 for a confidence level of 95%. Therefore, the change from pre to post-test for these data was not considered significant.

When asked on the Student Perceptions of Learning Survey to respond to the statement I feel that I learn best from hands-on activities like labs and projects, the average response was 3.9, which correlated to falling slightly below agree. When asked to respond to the statement, lecture helps me understand the material, the average response was a 3.8, which correlated to falling slightly below agree (N=12).

When asked to rate their level on confidence on the Student Confidence Survey, the average rating for confidence with the chapter material pre-treatment was a 3.0, which correlated to neutral. When asked to rate their level of confidence with the chapter material post-treatment, the average response was a 4.0, which correlated to somewhat confident. Seventy five percent of students reported an increase in confidence from pre to post-treatment (N=12) (Figure 13).

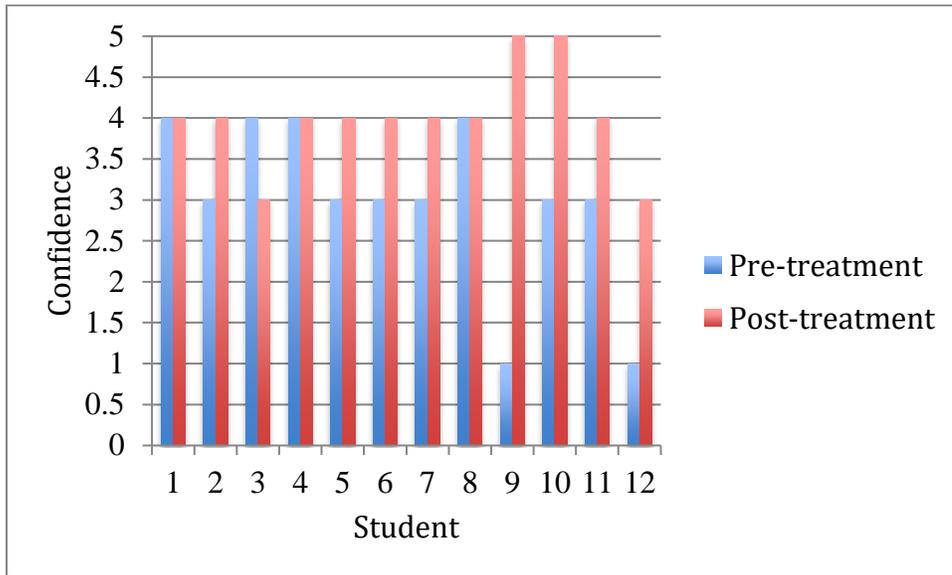


Figure 13. Student reported confidence for genetics unit, ($n=12$).

When asked during a post-treatment interview if they thought the table manipulatives better helped them understand the chapter material, all students responded that the remediation was helpful ($N=5$). In response to this same question, one student replied “yes, I was able to actually use my hands and move things to places and I didn’t have to just write things down.” When asked if there was anything that we could have done differently during the remediation session in order to even better prepare them for a retake, two of the five students who were interviewed responded by saying that they wished we had gone over the review guide again or otherwise indicated a desire for more direct instruction. One student said that it would have been helpful to play a question and answer type review game.

The results of the evolution unit remediation, which utilized science journaling as the remediation strategy, showed a negative average normalized gain of 16% from pre to post-test. The mean score on the pre-test was 54.9% while the mean score on the post-test was 47.5%. Fifty percent of the students who completed the remediation and took the

retake test were able to raise their score on the retake test. The median score shifted from 60% to 52.5% from pre to post-test. The maximum score increased from 67% to 80% ($N=8$) (Figure 14).

pre-test



post-test

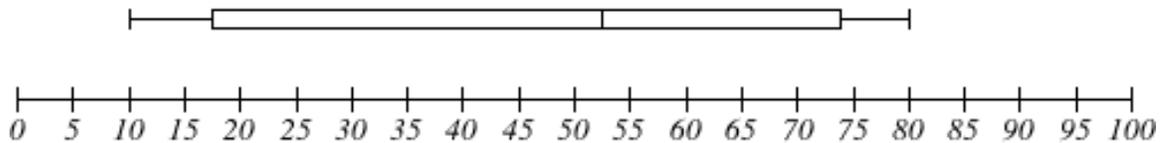


Figure 14. Pre and post-test data for evolution unit, ($N=8$).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. A p-value of .25 was calculated which was well above the confidence limit of .05 for a confidence level of 95%. Therefore, the change from pre to post-test for these data was not considered significant.

When asked to rate their level on confidence on the Student Confidence Survey, the average rating for confidence with the chapter material pre-treatment was 2.9, which correlated to falling slightly below neutral. When asked to rate their level of confidence with the chapter material post-treatment, the average response was 4.0, which correlated to somewhat confident. Seventy five percent of students reported an increase in confidence from pre to post-treatment ($N=8$)(Figure 15).

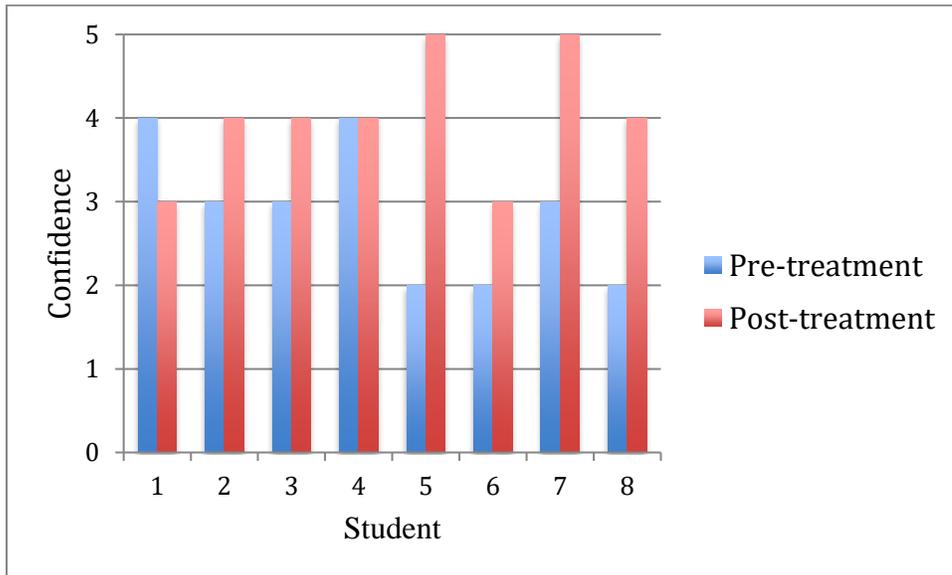


Figure 15. Student reported confidence for evolution unit, ($n=8$).

When asked during a post-treatment interview if they thought the remediation was helpful, one student responded, “It (the journaling) made me think more. I had to think out the concepts more because I had to write them out.” The same student went on to say that she felt “very confident” when taking the retake test, compared to not confident at all for the first attempt at the chapter assessment. She expressed that she probably could have studied more for the first test, but felt prepared after having to do the journaling, which made her study. When interviewed, another student expressed that for some reason, the material in the chapter “just wasn’t clicking for some reason”. When asked if he thought the journaling was helpful, he said, “I feel like it made me sit down, get it done, and just do it. At first I came in thinking, ‘I can’t believe I have to do this’, but then after, I felt like it forced me to sit down and do the review which I needed.” When asked during the interview what we could have done during the GAELS period in order to better help them understand the material, none of the four student interviewed had a solid idea of what might have helped them better prepare for the test other than what was

already done. Students gave answers like, “I don’t know, maybe go over stuff more” or simply stated that what we did was fine.

When asked to rate their perceived learning style on the student perceptions of learning survey, students ranked the statement, I learn best from hands-on activities like labs and projects, an average of 4.1 which correlated to falling slightly above agree. The same students rated the statement lecture helps me understand the material a 3.9, which correlates to falling slightly below agree.

The results of the classification unit remediation, which utilized science journaling as the remediation strategy, showed an average normalized gain of 6% from pre to post-test. Fifty-six percent of students who completed remediation and retook the test were able to raise their scores from pre to post-test. The median score decreased from 52 to 45 percent from pre to post-test ($N=9$)(Figure 16).

pre-test



post-test

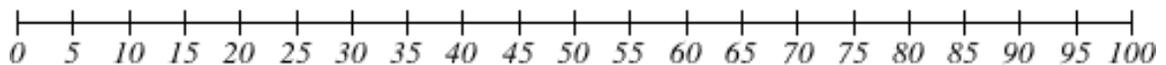
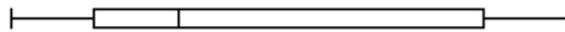


Figure 16. Pre and post-test data for classification unit, ($N=9$).

An unpaired two-sample two-tailed t-test was used to determine if these data were significant. A p-value of .42 was calculated which was well above the confidence limit of

.05 for a confidence level of 95%. Therefore, the change from pre to post-test for these data was not considered significant.

When asked to rate their level on confidence on the Student Confidence Survey, the average rating for confidence with the chapter material pre-treatment was 2.7, which correlated to falling slightly below neutral. When asked to rate their level of confidence with the chapter material post-treatment, the average response was 3.9, which correlated to falling slightly below somewhat confident. Seventy-two percent of students reported an increase in confidence from pre to post-treatment (N=7)(Figure 17).

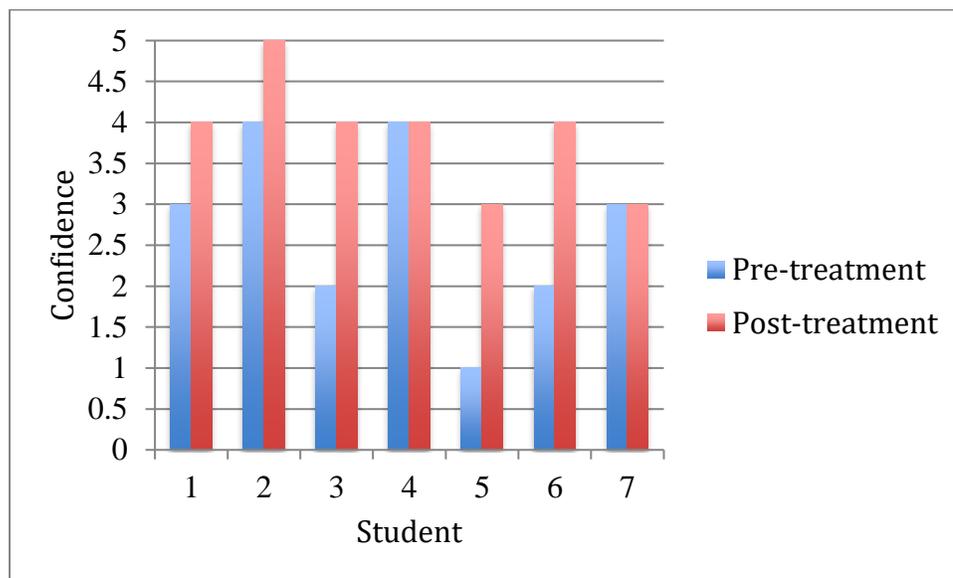


Figure 17. Student reported confidence for classification unit, ($n=7$).

When asked during a post-treatment interview if they thought the remediation was helpful, one student responded, “I feel like the stuff in the videos I already knew, but I thought the group work during GAELS period was pretty helpful.” When this same student was asked how confident they felt in regards to taking the retake test, they specified, “after coming to GAELS, much more confident.” Another student, when asked if they thought the remediation was helpful, responded, “the group work during GAELS

was okay, but I really like the videos because if I got lost, I could go back on the videos and replay them.” This same student reported that they felt much more confident in regards to taking the retake test than they felt in regards to taking the chapter test during their first attempt.

When asked on the Student Perceptions of Learning Survey to rank their level of agreement with the statement I learn best from hands on activities like labs and projects, students ranked this question an average of 4.1, which correlated to just slightly above agree. When this same group was asked to do the same for the statement, lecture helps me understand the material, students ranked this statement 2.6, which correlated to falling between disagree and neutral.

Combined Data

When all of the data were combined for each strategy (both units for which each strategy was used), each of the strategies yielded the following normalized gains:

- Science journaling: 10%
- Table Manipulatives: 9%
- Concept Mapping: 9%
- Flipped Classroom: 15%

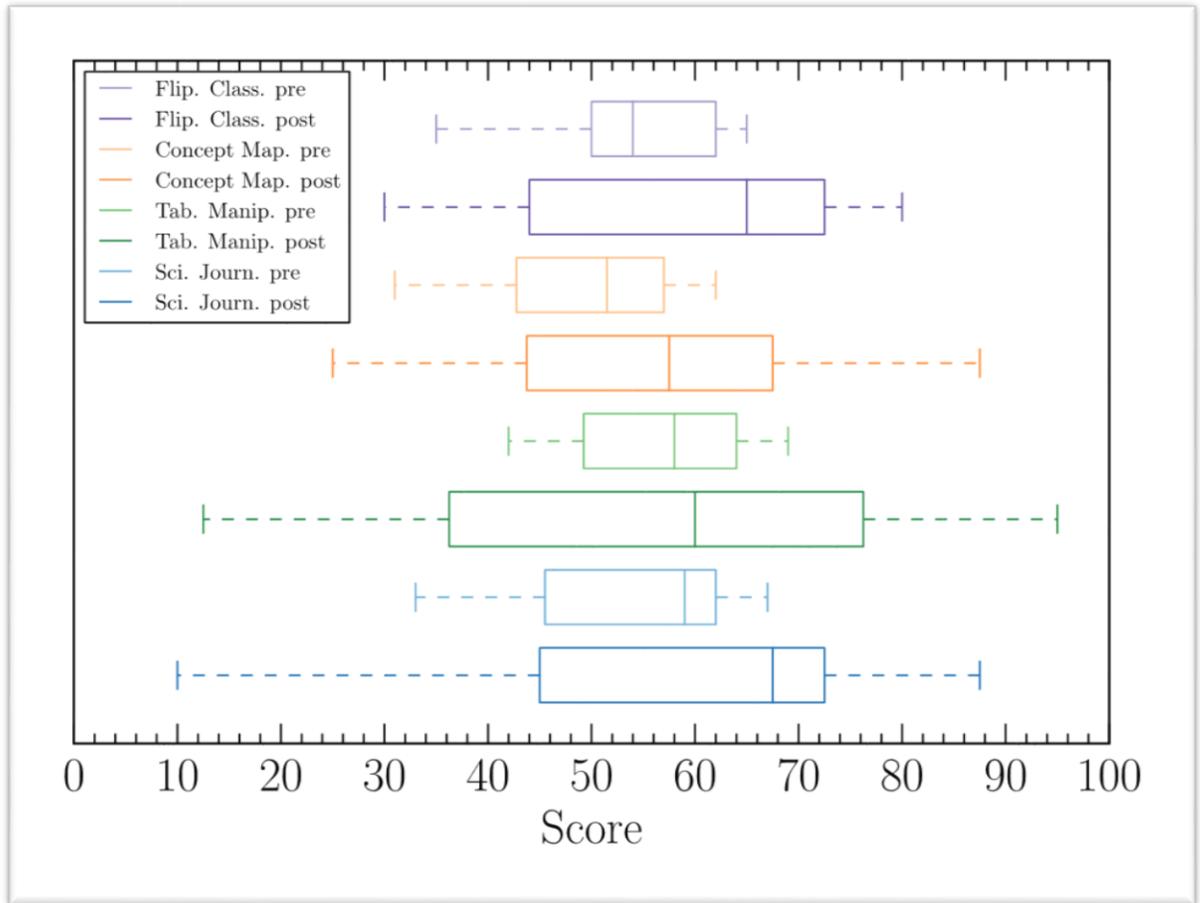


Figure 18. Cumulative summary of combined strategies, ($N=84$).

INTERPRETATION AND CONCLUSION

The goal of this project was to determine which of four strategies was most effective when used as a remediation technique for students who scored less than 70% on their first attempt at a chapter assessment. Although some strategies appeared to have a positive impact on student gains from pre to post-test, all strategies varied in their effectiveness from unit to unit. No individual technique had overwhelmingly positive results for every unit. These results might suggest that certain chapters lend themselves more to a given strategy than others. However, the mixed results could also simply be a

function of the group of students who attended each session. While a few students needed remediation for several chapters, and were therefore present for several of these remediation sessions, each chapter brought in several new students, some of whom had not previously performed poorly on an assessment before, nor did they after. This resulted in a different group of learners, each with a unique set of learning styles, attending each remediation session. It could very well be the case that when a strategy was successful it was because it appealed to the learning styles of the students who attended any given remediation session.

The mixed results could also be related to the implementation of the strategy, or even the group size during the review. Often times, review sessions had up to thirty students present (although not all students returned to take the retake exam and are therefore these students are not represented in the data). Some strategies, such as table manipulatives, required a substantial amount of teacher input, as I asked groups to check with me after each bag before moving on. With a large number of groups in the classroom, it was challenging to give each group the time they needed to explain why they placed the manipulatives in the way they did. Sometimes, impatient from waiting, groups would re-bag the manipulatives before I had a chance to talk through their solution. Due to the fact that I asked students to take pictures as they went and submit these pictures to me, I was able to see later if a group had errors, and several groups moved on having had a few things out of place, simply because I was with another group and couldn't get to them in time.

Flipped classroom also had challenges for implementation. Getting students to watch the videos at home before attending GAELS was difficult. A large percentage of

students did not watch the videos. This was not due to lack of accessibility, as all students have access to their own school-issued iPad device, WiFi at home, and high speed WiFi while on the school campus. Students chose to not complete the assignment. In one instance, I came across three students who had forgotten to watch the review videos and only had a few minutes before GAELS period. These students were ‘watching’ the videos with the sound off, and guessing on the questions as they popped up. The app tracks time spent watching the video, but this does not prevent students from simply leaving the video playing without actually watching or listening to the video. I discussed with these students the importance of integrity on assignments, but I can’t know for sure how many other students completed the review video portion of the flipped classroom approach in this manner. The effectiveness of each strategy for each unit is outlined separately below.

Science Journaling

Science journaling was an effective remediation strategy for the meiosis unit, but was not an effective strategy for the evolution unit. One notable variable is that spring break separated the original test and retake test for the evolution unit. Although students were exposed to a thorough review following the break, the amount of time between originally learning the material and reviewing for the retake for those students in need of remediation was substantial.

For the meiosis unit, students were asked to first reflect on what they felt they most needed to review. Then, students were asked to define a few chapter terms at the beginning of their entry and respond to a few content questions. Finally, students were provided with cut-outs and asked to color them, place them in order, and glue them into

their journals. Finally, students were asked to complete a personal reflection and respond to the statement “I feel better about...but I feel that I still need to review _____ in order to prepare for the retake”.

The students who attended the meiosis remediation saw themselves as hands-on learners, as evidenced by their relatively high ranking of 4.75 when asked to respond to the statement, I feel I learn best from hands on activities like labs and projects. These same students responded to the survey with a low rating for their ability to learn from listening, or lecture. According to the students’ perceived learning styles, science journaling, which is hands-on and involves little to no listening or lecture, is a good match (Figure 18).

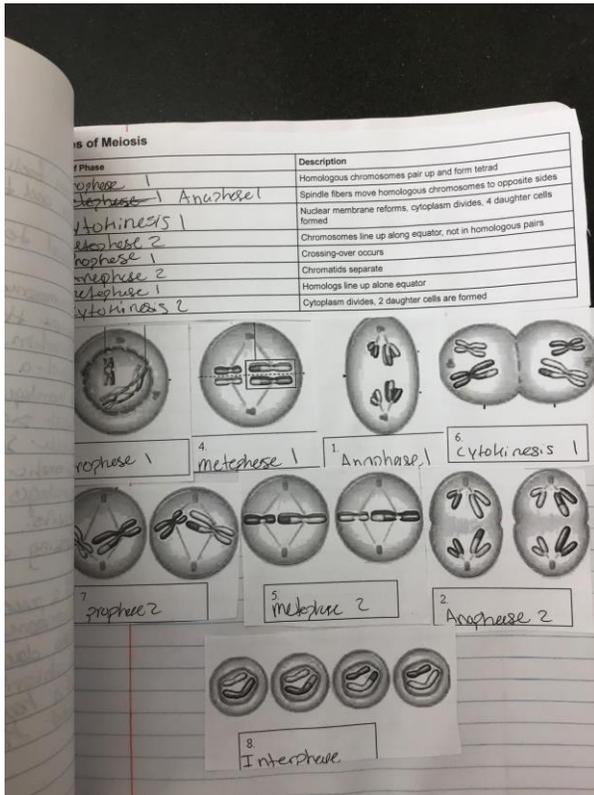


Figure 19. Student science journal entry.

Science journaling did not appear to be as effective a remediation strategy for the evolution unit as it was for the meiosis unit. Although 50% of students were able to raise their score from pre to post-test, the average normalized gain was negative, with many students performing very poorly on the retake, as low as 10%.

The students who participated in this remediation ranked themselves higher as hands-on learners than auditory, but not quite as high as the group that participated in the meiosis science journaling. They completed journaling in a similar way to those students who participated in the 11.4 remediation, and the chapter material lent itself well to reflection and journaling. For example, students were asked to sketch diagrams representing convergent evolution, adaptive radiation, and co-evolution and complete two personal reflections, one at the beginning of the journal entry, reflecting on what they felt they most needed to study, and one at the end reflecting on what they felt better about and what they needed to still review.

The main factor affecting the low retake scores for this unit may have simply been timing. With a week of spring break separating students from the unit itself and reviewing for the retake, retention was poor and students were mostly unsuccessful.

Table Manipulatives

Table manipulatives appeared to be an effective strategy for the cellular respiration unit remediation, with an average normalized gain of 20% from pre to post test. However, this strategy was somewhat ineffective when used for the genetics unit.

The table manipulatives set for chapter nine included two Venn diagrams and a large number of terms. Students were asked to place the terms in the diagrams under the correct category. For example, students were asked to place the term *oxygen required*

either under anaerobic respiration, aerobic respiration, or both. Students were also given a bag of table manipulatives containing a large mitochondria, arrows, and terms. Students were asked to place these things on their desks to represent the process of cellular respiration. The three bags combined represented a large amount of the chapter content. While it was difficult with other remediation strategies to incorporate all chapter material into a single hour of remediation, or a single, say, science journal entry, this particular strategy encompassed the vast majority of what students had learned in the chapter regarding cellular respiration. This could explain the relatively high normalized gain of 20%. One student was able to increase his score to 90% from his original score of 66%. Interestingly enough, this group of students had very little self-reported preference in their learning styles. The rankings for students reporting learning best from lecture and hands-on activities were very close to the same. Both fell just slightly below agree when asked if they learn best from hands on activities or from listening. This suggests that this group had no strong preference for learning style as a group. The way in which the remediation was conducted, and the fact that the manipulatives themselves addressed a large percentage of the chapter material, may have explained the high scores. Students worked diligently in groups to complete the remediation, and feedback from students regarding the remediation was overwhelmingly positive. A few students who ended up in the next chapter remediation, which utilized science journaling instead, stated during interviews that they would have preferred we use table manipulatives again. Figures 20 and 21 show students working on two different sets of table manipulatives.

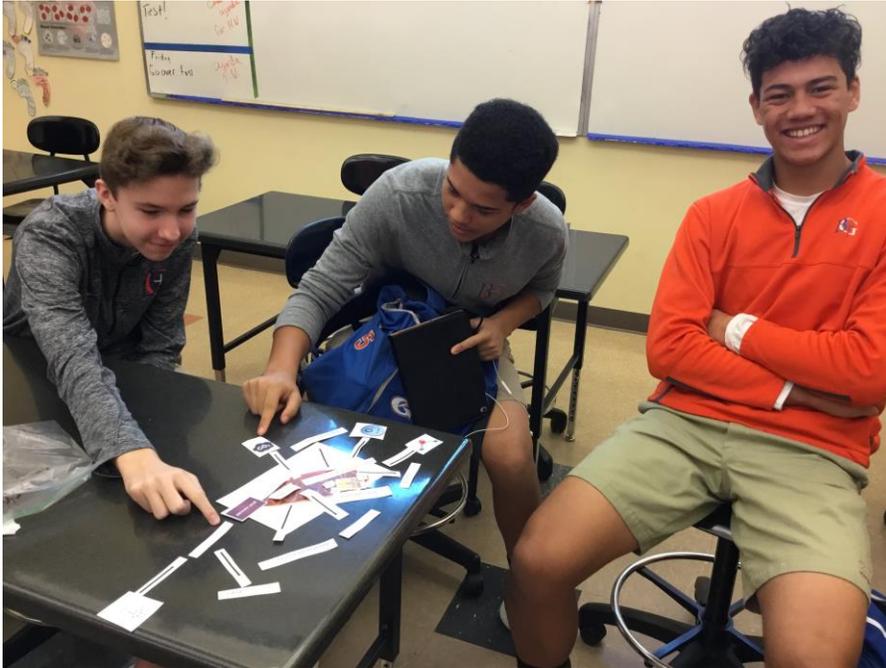


Figure 20. Students working on table manipulates set.

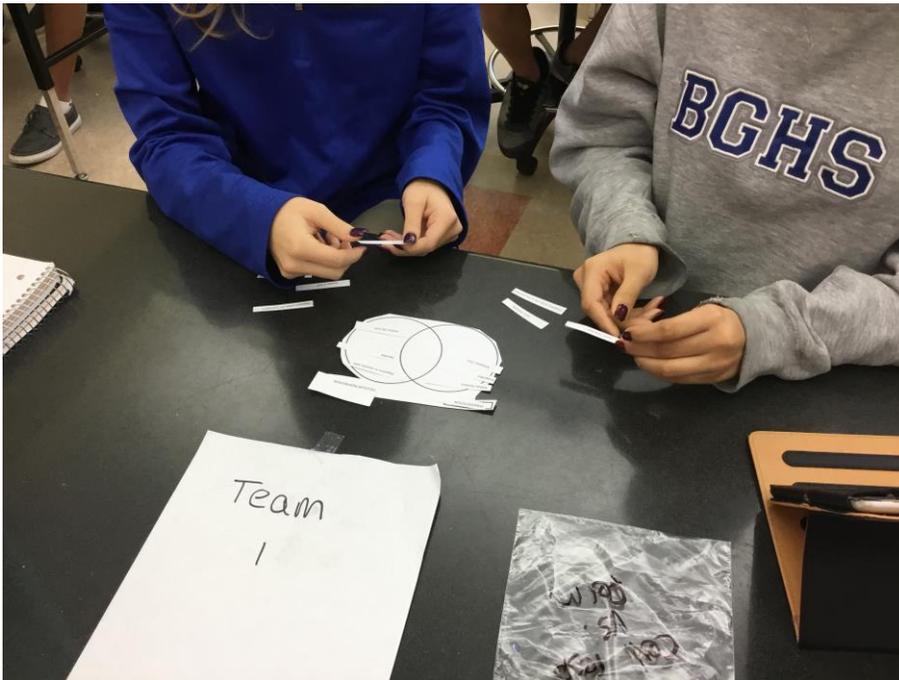


Figure 21. Students working on a table manipulates set.

Table manipulatives were somewhat ineffective for the genetics unit. Although fifty percent of students were able to raise their scores from pre to post-test, the overall

average normalized gain was negative. The group of students who participated in the genetics remediation were similar to those who participated in the chapter 9 remediation in that they did not self-report a strong preference towards any particular learning style. The difference in effectiveness may have more to do with the content of the chapter lending itself better to other strategies. When I designed the manipulatives I struggled with coming up with things that students could physically manipulate in order to review the material. The table manipulatives for this unit consisted of two Punnett Squares (both mono and Dihybrid), which students could physically put together, as well as a blood typing example with blood type allele cards. Overall, the design of the manipulatives may not have addressed as many chapter misconceptions or as much chapter content as desired. Though they completed the remediation, students may have left GAELS with additional unaddressed misconceptions about genetics if they didn't spend some additional time reviewing the chapter on their own, or using the chapter review guide to review for the retake, which is something that students who end up in need of remediation typically don't do on their own. Science journaling may have been a more effective strategy for this unit because many of the concepts in the unit are complicated, and difficult to illustrate using table manipulatives, but may be easier to review using prompts and reflections. Figure 22 below shows a student working on a table manipulatives set.

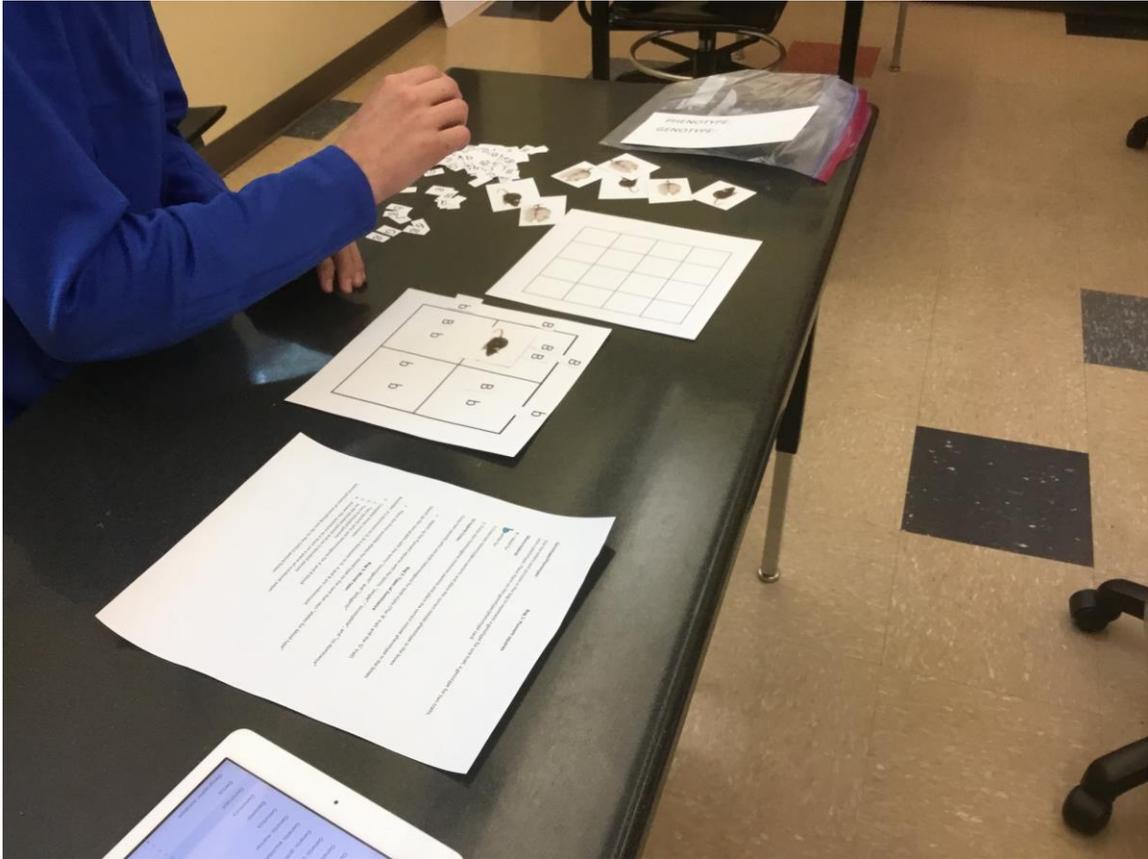


Figure 22. Student working on table manipulatives set.

Concept Mapping

Concept mapping was an effective remediation technique for the unit over cell transport, but appeared to be ineffective for the photosynthesis unit. The group that attended the cell transport remediation was smaller than the group that attended the photosynthesis remediation. This difference in implementation for each chapter may have affected the outcome for each strategy.

It is possible that the nature of the cell transport unit and the content within may explain why concept mapping seemed to be an effective strategy for this unit. In order to understand cell transport, students must be able to recognize patterns and make connections between various topics of the unit. While this is true for any unit that we do,

I believe that it is of particular importance in the cell transport unit. For example, students were taught that there are two main types of cell transport- active and passive. Students were also taught that simple diffusion, facilitated diffusion, and osmosis are all means of passive transport. Often times, students will hear “passive transport” and “diffusion” and think of these two terms as completely unrelated types of transport, missing the connection between these two terms.

When creating a concept map, a proficient student was able to create a bubble on their concept map that said “passive transport” and then draw connection lines leading to various types of passive transport. By making these types of connections, students demonstrated a higher level of learning that extended beyond remembering terms and into understanding. A number of students rushed through the creation of the map and ended up with a number of conceptual errors on their final maps, but many students took the review seriously and completed well thought out concept maps.

The group of students who attended the cell transport remediation indicated on their Student Perceptions of Learning survey that they agreed that chapter concepts were intricately connected, and also indicated that they did not struggle with making connections between concepts within a chapter. Although students said that this was not something they struggled with, a strategy designed to help students make chapter connections (concept mapping) proved to be very effective. For many strategies, students’ responses on the perceptions of learning survey or confidence survey did not align with the overall results. Figure 23 below shows an example of a student-created concept map.

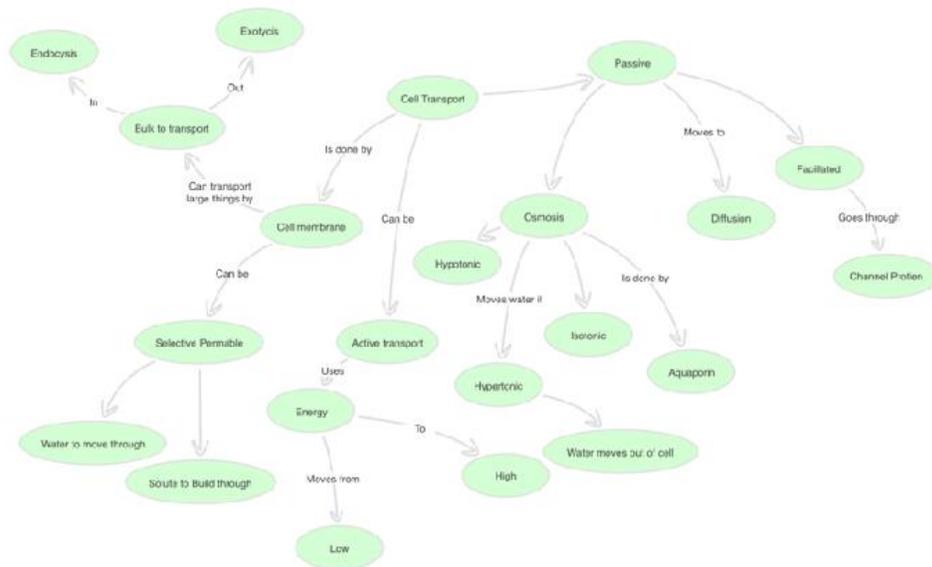


Figure 23. Student-created concept map.

Photosynthesis may have not lent itself as easily to the creation of a concept map as a review strategy. Several students didn't seem to know how to get going, so I helped them get started by creating two bubbles on their concept map, leading from the word photosynthesis, I wrote, "light dependent" and "light independent" and asked students to continue from there with the list of required terms. A few students were able to move on from there and went on to use all required terms with few errors, but many students seemed to rush through the concept map, simply putting the required terms on the map to get the map done, with very few logical connections between terms.

Flipped Classroom

Flipped classroom showed positive normalized gains for both units for which it was used. However, flipped classroom only showed statistically significant results for the mitosis unit. A common theme emerged when students were asked about using videos as

part of their review. A number of students stated that the videos were helpful because, unlike an in-class lecture, they could stop the video and replay parts that they did not understand. While students can always ask questions during in-class lecture if they didn't understand something, some students may be hesitant to do so. Students stated that being able to stop the video and replay parts helped them if they zoned out or just didn't catch something that was said.

A few students stated that the videos mostly contained information that they already knew, but the in-class group review was very helpful. These students reinforced the main idea behind flipped classroom, which is freeing up in-class time for group activities rather than lecture.

The students who attended remediation for both units for which flipped classroom was used reported a strong preference for hands-on activities as opposed to lecture. It is possible that this strategy was particularly useful for these students because the videos allowed the students to review lecture material at their own pace- material that they may have missed during the in-class lecture. It also provided these students with a hands-on way to review the material with a group, following watching the videos, which may have more strongly aligned with their learning styles.

One issue with this remediation approach was lack of accountability. The students who typically ended up in need of test remediation were the same students who struggled with turning in work on time and completing assignments. Getting these students to watch the videos was challenging. During both units, I observed a few students who hadn't watched the videos as homework attempting to "watch" the videos during class, prior to the GAELS period. These students had the videos playing without sound, and

they were guessing as the questions popped up. The EdPuzzle app would show that they watched the video, even if they watched it without sound. I made these students actually watch the videos before completing the in-class portion of the remediation, but it is difficult to ascertain what percentage of students completed the at-home portion of the review in this way. For this reason, flipped classroom remains a challenge for students who aren't accountable for homework. Figure 24 shows a group of students working collaboratively on a group review session following watching review videos at home.

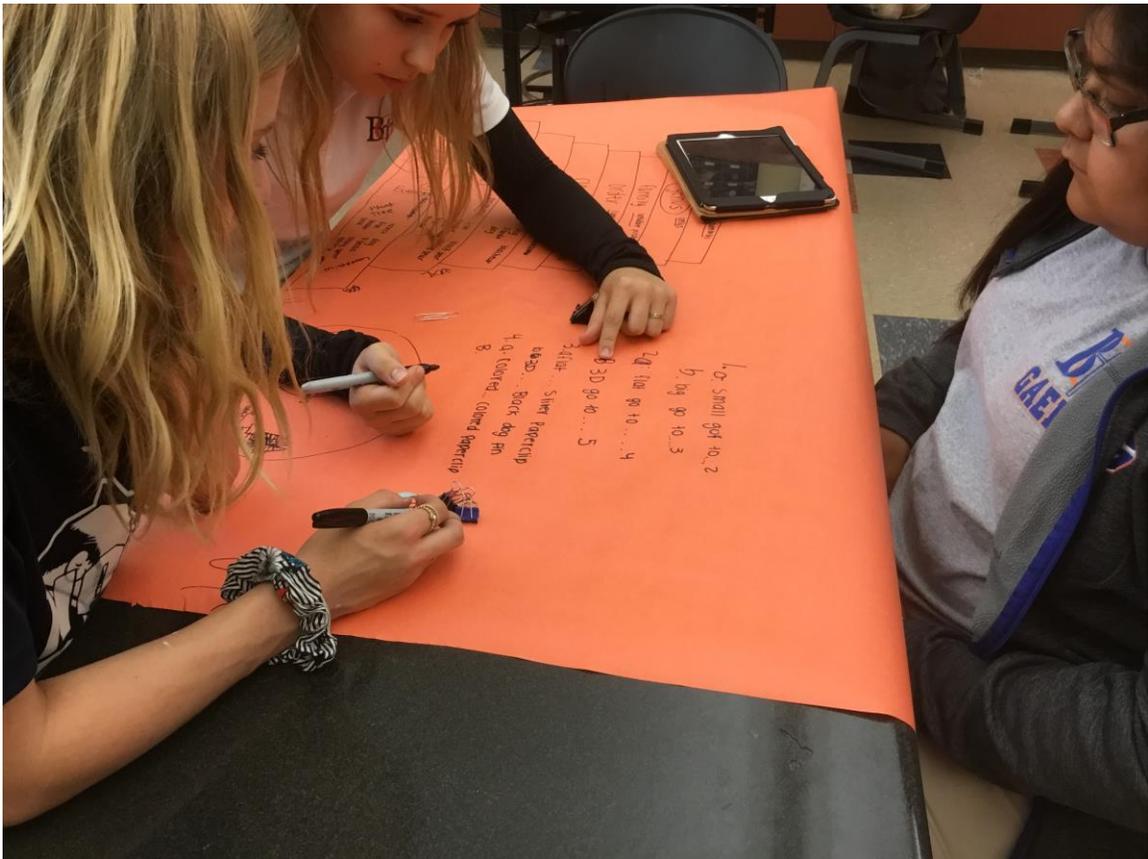


Figure 24. Students working on collaborative group review.

Overall

When all of the data were combined for each strategy (both units for which each strategy was used), flipped classroom produced the highest gains (15%), followed by

science journaling (10%). Table manipulatives and concept mapping were tied for third, each producing a normalized gain overall of 9%. However, The individual unit with the highest overall gain was the cell transport unit, which utilized concept mapping. It is interesting to see that a strategy that produced a low overall gain when units were combined also produced the highest individual gain for any unit (31%). This supports the idea that each unit may lend itself very strongly to a particular strategy over another. The second highest individual gain (29%) was the meiosis unit, which utilized science journaling. Science journaling was also second overall when units were combined.

VALUE

The GAELS period was instituted five years ago. In that time, I have heard my colleagues express mixed feelings about the effectiveness of having this time available for remediation. Parents have expressed concern that the time devoted to GAELS period could be better spent on class time. At times, I have echoed the concerns of others and expressed my own concerns that GAELS period simply wasn't working. Students who attended GAELS remediation and went on to a second attempt at a chapter assessment often scored the same or lower than their first attempt on chapter assessments. Those same students went on to fall even more behind as time progressed due to the cumulative nature of the courses in which they were struggling.

During the time that I was conducting the research for this project, colleagues often asked how it was working. In informal lunchtime discussions, I let my colleagues know which strategies seemed to be proving most useful and which hadn't worked. Many expressed interest in reading the results when I was finished so that they could possibly

alter the way in which they conduct their own remediation periods. In this way, I hope that the results of this project will not only impact the way that I conduct remediation in the future, but also the classrooms of my colleagues.

One of the most motivating aspects of doing this project was seeing the change in attitude of several of the students who attended the GAELS remediation. In the past, I've struggled with students who were frustrated with having to attend GAELS at all, as the student perception of the GAELS period was that it was a free period if one was lucky enough to not be assigned to any particular teacher during this time. As such, in the past, students have walked into the room for GAELS period and stated things like, "how long will this take?" or, "do I really have to be in here? I scored a 68% so I can't raise my grade by that much." Struggling with student attitudes towards having to do remediation was often discouraging for both students and myself. I often felt like the negative attitude in the room during these periods was adversely affecting students' perceptions of the course overall, and I often wondered if it would be best to forgo remediation, as it didn't seem to be helping, and students didn't take it seriously.

During the course of this project, I witnessed a gradual change in student attitudes, especially among those who attended more than one GAELS period. Over time, students began to say things more along the lines of, "what will we be doing this time for GAELS?" Few students asked how long it would take, as they began to expect a full period of activities. While some of the remediation strategies were effective and others not so much, this change in attitude was refreshing to see. According to Lawrenz, (1976) student perceptions of the learning environment have a substantial effect on their attitudes towards science in general. Lawrenz stated,

Student attitude toward science has been shown to be correlated to student perception of the classroom environment. Biology and Chemistry teachers in particular should be careful to create a harmonious low-conflict environment if they hope to foster more positive student attitudes. (Lawrenz, 1976, p. 513).

Lawrenz went on to say that biology teachers should be the most careful to foster a positive learning environment, as biology is often the first science that students take during high school and might set the tone for student attitudes towards science overall.

As the course progressed, students began to embrace GAELS period remediation sessions. Some students who attended more than one chapter remediation even began to request certain strategies. At one point, a student said, “will we be getting into groups and doing the baggies (table manipulatives) again?” This increase in student interest, engagement, and participation in the GAELS period is something that I plan to share with colleagues, even more so than which strategy seemed to work the best. No one strategy is ever going to work for all learners, but the changes in attitudes and engagement I witnessed were not overlooked. Perhaps by conducting the remediation sessions using the new strategies, I myself took the GAELS more seriously and changed the classroom environment, the effects of which had positive impacts on the students’ own perceptions of that time.

I plan to conduct GAELS periods in a similar fashion next year, with some modification to the process. One change I hope to make is to use all four of these strategies with each chapter remediation. Student learning styles vary. Some students like to work in groups, others individually. Some students are kinesthetic learners, others auditory or visual. Appealing to diverse learning styles is arguably more of the most challenging jobs of an educator. For this reason, I hope to combine strategies next year.

I've been considering using stations during the GAELS period. One station might have table manipulatives set up while another station requires students to make a group concept map. Students could watch review videos before attending GAELS and go home with a science journal entry to complete as their ticket to retake the test. While using all of the strategies at once might be overwhelming and require some tinkering in order to get it to work, I am optimistic about the future of remediation periods.

Two of the strategies I used for this project were new to me. I had never used science journaling or concept maps in the classroom prior to this project. Seeing the results of this project has encouraged me to diversify my teaching strategies in the regular classroom setting. I think that continuous use of science journaling throughout the year could benefit students, based on the results of using this strategy during remediation. While concept mapping was a difficult challenge for students, I could see myself creating concept maps as a whole-class activity. I'd like to use table manipulatives as part of our chapter reviews in the future and, with approval of administration, attempt a flipped classroom approach for some chapters.

Having tried all of these new strategies this year, I find myself far more comfortable with the idea of trying them in the regular classroom with large numbers of students. This project has encouraged me to try some new things, many of which had positive results. It also helped me overcome some fears I had regarding trying new things that I had never done before. Trying them with small numbers of struggling students first was an effective way to explore these new strategies to the benefit of many students.

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APPENDICES

APPENDIX A
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Jocelyn Rice and John Graves
FROM: Mark Quinn *Mark Quinn*
 Chair, Institutional Review Board for the Protection of Human Subjects
DATE: October 31, 2017
RE: "An Investigation of Several Teaching Strategies for Use as Remediation Techniques in a High School Biology Classroom" [JR103117-EX]

The above research, described in your submission of October 31, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

INITIAL CHAPTER ASSESSMENT EXAMPLE

Name: _____ Class: _____ Date: _____

ID: A

CP Genetics 11.1-11.3**Multiple Choice***Identify the choice that best completes the statement or answers the question.*

- _____ 1. The different forms of a gene are called
- traits.
 - pollinations.
 - alleles.
 - hybrids.
- _____ 2. If a pea plant's genotype for height is tt , what is true of its parents?
- Both parents were tall.
 - Both parents were short.
 - Both parents contributed a recessive allele.
 - Both parents contributed a dominant allele.
- _____ 3. The principles of probability can be used to
- predict the traits of the offspring of genetic crosses.
 - determine the actual outcomes of genetic crosses.
 - determine which species should be used in genetic crosses.
 - decide which organisms are best to use in genetic crosses.
- _____ 4. A heterozygous tall pea plant is crossed with a short plant. The probability that an F_1 plant will be tall is
- 25%.
 - 50%.
 - 75%.
 - 100%.
- _____ 5. Organisms that have two identical alleles for a particular trait are said to be
- hybrid.
 - homozygous.
 - heterozygous.
 - dominant.

Name: _____

ID: A

		<i>Tt</i>	
		<i>T</i>	<i>t</i>
<i>TT</i>	<i>T</i>	<i>TT</i>	<i>Tt</i>
	<i>T</i>	<i>TT</i>	<i>Tt</i>

<i>T</i> = <i>Tall</i>
<i>t</i> = <i>Short</i>

Figure 11-1

- _____ 6. In the Punnett square shown in Figure 11-1, which of the following is true about the offspring resulting from the cross?
- About half are expected to be short.
 - All are expected to be short.
 - About three fourths are expected to be tall.
 - All are expected to be tall.
- _____ 7. How many different allele combinations would be found in the *gametes* produced by a pea plant whose genotype was *RrYY*?
- 2
 - 4
 - 8
 - 16

Name: _____

ID: A

		<i>RRYy</i>			
		<i>RY</i>	<i>Ry</i>	<i>RY</i>	<i>Ry</i>
<i>RrYy</i>	<i>RY</i>	<i>RRYY</i>	<i>RRYy</i>	<i>RRYY</i>	<i>RRYy</i>
	<i>Ry</i>	<i>RRYy</i>	<i>RRyy</i>	<i>RrYy</i>	<i>RRyy</i>
	<i>rY</i>	<i>RrYY</i>	<i>RrYy</i>	<i>RrYY</i>	<i>RrYy</i>
	<i>ry</i>	<i>RrYy</i>	<i>Rryy</i>	<i>RrYy</i>	<i>Rryy</i>

Figure 11-3

8. Use Figure 11-3 to answer the following question. If a pea plant that is heterozygous for round, yellow peas (*RrYy*) is crossed with a pea plant that is homozygous for round peas but heterozygous for yellow peas (*RRYy*), how many different **phenotypes** are their offspring expected to show?
- 2
 - 4
 - 8
 - 16
9. Roan cattle show codominance for the color of their hair. There are alleles for brown hair and white hair. What would you expect a heterozygous roan bull to look like?
- It would be all brown
 - It would be all white.
 - It would be spotted brown and white.
 - It would be light brown
10. A breed of chicken shows codominance for feather color. One allele codes for black feathers (B), another codes for white feathers (W). Two heterozygous chickens are crossed. What are the possible phenotypes of the offspring?
- black only
 - black and white striped only
 - Black or white only
 - black, white, black and white striped
11. Situations in which one allele for a gene is not completely dominant over another allele for that gene are called
- multiple alleles.
 - incomplete dominance.
 - polygenic inheritance.
 - multiple genes.
12. In rabbits, there are four different versions of the gene for coat color. What pattern of inheritance is this?
- incomplete dominance.
 - polygenic inheritance.
 - codominance.
 - multiple alleles.

Name: _____

ID: A

- ____ 13. Variation in human skin color and human height are examples of
- incomplete dominance.
 - codominance.
 - polygenic traits.
 - multiple alleles.
- ____ 14. Mendel crossed a purple flowered pea plant and a white-flowered pea plant and found that all the offspring from this first cross were purple. He therefore concluded that:
- white is dominant to purple
 - purple is dominant to white
 - purple and white are codominant
 - purple and white show incomplete dominance
- ____ 15. In humans, A is dominant to O, B is dominant to O and A/B are codominant. Which of the following pairs of genotypes for blood type results in the same phenotype?
- AA* and *AB*
 - BB* and *BO*
 - BB* and *AB*
 - BO* and *OO*

Blood Types	
Blood Type	Combination of Alleles
A	<i>AA</i> or <i>AO</i>
B	<i>BB</i> or <i>BO</i>
AB	<i>AB</i>
O	<i>OO</i>

Figure 14-2

- ____ 16. If a man with blood type A and a woman with blood type B produce an offspring, what might be the offspring's blood type?
- AB or O
 - A, B, or O
 - A, B, AB, or O
 - AB only

Completion

Complete each statement.

17. Due to the process of segregation, the two alleles for a trait separate during the production of _____.
18. You do a Punnett square and determine that for a cross between two given parents, there is a 1/4 chance of producing an offspring with a hitchhiker's thumb. What are the chances that those parents would produce two offspring who both have a hitchhiker's thumb?

Name: _____

ID: A

		<i>RrYy</i>				
		<i>RY</i>	<i>Ry</i>	<i>rY</i>	<i>ry</i>	
<i>RrYy</i>	<i>RY</i>	<i>RRYY</i>	<i>RRYy</i>	<i>RrYY</i>	<i>RrYy</i>	Seed Shape <i>R</i> = Round <i>r</i> = Wrinkled
	<i>Ry</i>	<i>RRYy</i>	<i>RRyy</i>	<i>RrYy</i>	<i>Rryy</i>	Seed Color <i>Y</i> = Yellow <i>y</i> = Green
	<i>rY</i>	<i>RrYY</i>	<i>RrYy</i>	<i>rrYY</i>	<i>rrYy</i>	
	<i>ry</i>	<i>RrYy</i>	<i>Rryy</i>	<i>rrYy</i>	<i>rryy</i>	

Figure 11-2

23. What is the **phenotype** ratio of the offspring of the plants in the Punnett square in Figure 11-2?
24. What is the probability that a cross between parents who are both homozygous recessive for trait will have offspring that are homozygous recessive for that trait? (give answer as a percent)

APPENDIX C
RETAKE TEST EXAMPLE

NAME _____ Pd. _____ DATE _____

11.4 Meiosis Retake

CP Biology

1. Explain the terms diploid and haploid. What kind of cells are diploid? What kind of cells are haploid?
2. A human body cell has 46 chromosomes, how many chromosomes are found in a human gamete cell?
3. Compare and contrast mitosis and meiosis. List at least *three differences* between the two processes. Include differences such as the type of cell and number of cells produced by each process, the phases of each, differences within the phases... etc.
4. Refer to the image below. Would this shoe collection most closely represent the chromosomes found in a diploid cell or a haploid cell? WHY?

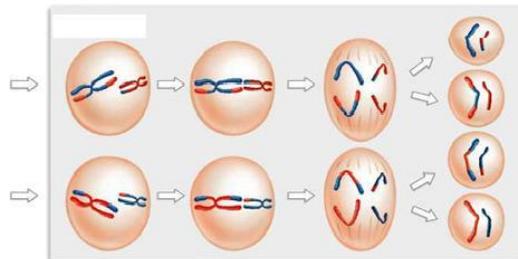


NAME _____ Pd. _____ DATE _____

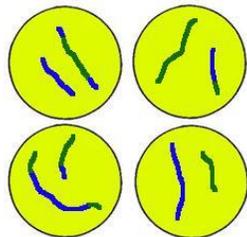
5. What is the difference between anaphase I and anaphase II of meiosis?

6. What is crossing over and why does it occur?

7. Does the picture below show meiosis I or meiosis II? Why?

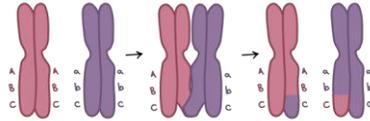


8. A parent cell undergoes meiosis and produced the four daughter cells shown below. How many chromosomes did the parent cell contain? How do you know?

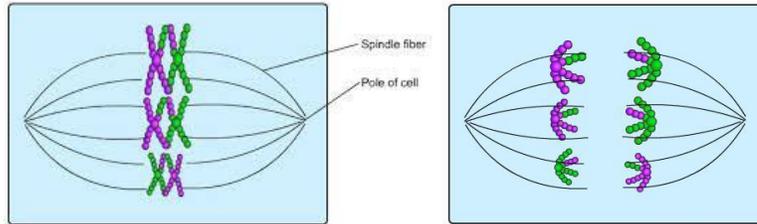


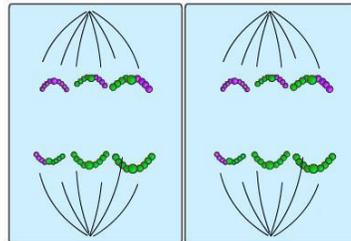
NAME _____ Pd. _____ DATE _____

9. What process is shown below?



10. Identify the following phases. Don't forget to put I/II





APPENDIX D

PRE AND POST-TREATMENT STUDENT CONFIDENCE SURVEY

Statement	Very Non-Confident	Somewhat Non-Confident	Neutral	Somewhat Confident	Very Confident
Heading into remediation today, my confidence with the chapter material was	<input type="checkbox"/>				
After completing the remediation today, my confidence with the chapter material is	<input type="checkbox"/>				

APPENDIX E
STUDENT PERCEPTIONS OF LEARNING SURVEY

Participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I learn best from hands-on activities like labs and projects	<input type="checkbox"/>				
Lecture helps me understand the material	<input type="checkbox"/>				
The concepts we learn in one chapter are related to concepts we learn in other chapters	<input type="checkbox"/>				
The concepts we learn throughout one chapter are related/connected to each other	<input type="checkbox"/>				
If I learn the vocab for the chapter, I should be able to do well on the test	<input type="checkbox"/>				
Seeing how different concepts throughout a chapter relate to one another is challenging for me	<input type="checkbox"/>				

APPENDIX F

POST-TREATMENT STUDENT INTERVIEW QUESTIONS

Participation in this research is voluntary and will not affect your grade or standing in the class in any way

Student Interview questions:

1. Walking into the chapter test, did you feel that you were properly prepared to take the test?
2. What do you think would have helped you better prepare for the test?
3. Do you feel anxious when taking tests?
4. Do you feel that you learn best through actively working on a project/assignment or listening to an explanation/lecture?
5. Do you feel that you are able to pay attention during lecture?
6. Did you feel that what we did for Gaels period today better helped you understand the material?
7. What could we have done today that you feel may have helped you better prepare for the retake?
8. How confident are you in regards to taking the retake test?
9. Is there anything else you'd like me to know?