THE IMPACT OF THE 5E LEARNING CYCLE ON SEVENTH GRADE LIFE SCIENCE STUDENTS' LEARNING AND RETENTION OF SCIENCE CONCEPTS

by

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ABSTRACT

Students participated in four instructional units related to genetics and the human body. Two treatment units were designed using the 5E Learning Cycle whereas two non-treatment units were designed using more traditional science teaching practices. To evaluate students' learning and retention of the science content the following data collection tools were utilized: pre-, post-, and delayed-post tests, performance assessments, and student generated concept maps. Results suggest that students made gains with both instructional methods but that there was not a clear distinction between which instructional style (5E or non-5E) was best.

INTRODUCTION AND BACKGROUND

Classroom Research Project Purpose

While I feel like I have mastered a wide variety of reading and writing strategies, cooperative group activities, assessment techniques, and classroom management in my 17 years as a middle school science teacher, one area I especially wanted to improve was my skills in guiding students through inquiry. I found that when time and resources were at a premium, I often reverted to more traditional teaching methods, ones modeled for me by most of my K-12 teachers and college professors. This led to my question: How can I improve my inquiry-based teaching skills and ultimately my students' inquiry skills?

My classroom research project goal was to improve my inquiry-based teaching skills by implementing the 5E Learning Cycle. This project allowed me to monitor my transition to more inquiry-based teaching practices while comparing students' learning and retention of science content in traditional versus 5E Learning Cycle units. The timing of this project was especially important because Montana recently adopted a slightly modified version of the Next Generation Science Standards for K-12 science education. The new standards rely heavily on science and engineering practices, including inquiry. The comparison of pre- and post- unit assessments throughout the action research project allowed students, parents, and administrators to see the growth students demonstrated during the transition to the new standards.

This classroom research project took place at Polson Middle School in Polson, Montana. The school is a public school serving 547 fifth through eighth grade students. All 128 seventh grade life science students were involved in this classroom research project. The middle school is one of four schools in the rural K-12 district that serves Polson, Montana and outlying areas. Polson lies within the border of the Flathead Indian Reservation which was set aside for the Salish, Kootenai, and Pend d'Oreille people though today the population is much more diverse than just the three original tribes.

Next year, I will switch to teaching both seventh- and eighth-grade sciences, life science and physical science respectively. Teaching both grade levels will provide the opportunity to collaborate with another colleague in my building for the first time in six years. I regularly collaborated with colleagues at my previous district as we had multiple science teachers at each grade level. I look forward to the renewed opportunity to collaborate with a peer and will share the 5E Learning Cycle units, and lessons learned through the action research process, with my colleague. The capstone process provided ample opportunities for growth for myself and my students and will positively impact the science department in the upcoming school year and beyond.

Action Research Questions

The main question I sought to answer was "What impact does the use of the 5E Learning Cycle, an inquiry-based format, have on seventh-grade life science students' learning and retention of science concepts?" Three sub-questions guided my classroom research project development and data collection as I attempted to answer my main question:

- How does the 5E Learning Cycle impact students' learning of science concepts?
- How does the 5E Learning Cycle impact students' retention of science concepts?
- How does implementing the 5E Learning Cycle impact me as a teacher?

Action Research Project Support Team

Throughout the action research process, many individuals' support proved invaluable. My formal support team included education advisor Walter Woolbaugh and science advisor Charles (Bill) McLaughlin. At work, science colleagues Tami Morrison and Mark Rochin allowed me to bounce ideas off them during our Professional Learning Committee times and at other times throughout the day. Mark was also completing his masters, though in administration, at the same time and we often reminded one another of how close we were getting to our long-term goal. Mark and Tami provided feedback on the difficulty of various assessment tools in an attempt to ensure that assessments across units were at similar difficulty levels. At home, my husband and social studies teacher Matt Dalbey provided emotional support and critical perspectives on data and trends. In the digital learning environment, my 2018 MSSE capstone cohorts provided critical feedback, encouragement, and inspiration leading up to and throughout the action research project. I am thankful to have so many supportive professionals come along side my MSSE journey.

CONCEPTUAL FRAMEWORK

The Constructivist Theory

The constructivist theory, shaped by three centuries of work, provides the foundation for the 5E Learning Cycle. Key contributors to the theory include German philosopher Immanuel Kant, Soviet psychologist Lev Semyonovich Vygotsky, American education reformer John Dewey, Swiss psychologist Jean Piaget, and American physicist, historian, and philosopher Thomas Kuhn. The main premise of constructivism is that children learn by building understanding within their own minds, as opposed to being told information by others (Llewellyn, 2014).

Kant (1781) argues that much of our reality is in fact shaped by our mind. Our brain absorbs input from the senses and then manipulates that information to make meaning. This means that an individual's perception of the world is shaped by how the individual's mind resolves the incoming information. In the educational setting, this means that classrooms are filled with unique minds, each forming their own understandings of classroom experiences. Thomas Kuhn (Matthews, 2004) spoke to this issue as well when he established that each learner's unique mind interprets the outside world and creates their own personal reality which means that each person's "reality" is different. He used this to explain why conceptual changes in individuals (microchanges) are necessary for macrochanges in science understanding to occur. This explains in part the extended time it takes for societies to accept new understandings in science. Copernicus published his solar centric model of the universe in 1543 yet it took over a century to abandon Ptolemy's earth centric model, formulated in 150 B.C., in favor of the scientifically accurate Copernican model (Jones, 2003; Reibeek, 2009). The reluctance to let go of Ptolemy's model is evident even today when we talk about the sun rising and setting. In modern times, we can see evidence of the need for microchanges in understanding to occur at the personal level before society is willing to accept macrochanges in scientific understanding; since French scientist Joseph Fourier's first use of the term "greenhouse effect" in 1824, there has been mounting evidence that human activities can and are causing climate change yet there is considerable resistance to accepting responsibility for doing so ("A brief history of climate change," 2013). When working with students, it is important to remember that for learning to occur, opportunities must exist for them to achieve microchanges in their understanding.

To provide students with an abundance of input from which to form the understandings Kant and Kuhn indicated, John Dewey argued that teaching and learning should be an active process in which students have opportunities to solve problems they are interested in as thinking, and therefore learning, occur when people confront problems. Dewey suggested that teachers can sometimes present information to students, but that students must use that information in some way to build understanding and retain the knowledge (Llewellyn, 2014).

Jean Piaget (Llewellyn, 2014) stressed that knowledge is built while students experiment with objects in their environment. As they interact with those materials, they use personal schemas, mental models, to interpret and assess their experiences. This means that students fit new experiences in with old mental models which can be riddled with naiveties or misconceptions. Teachers therefore need to provide opportunities and guidance for students to reconcile their old schemas with new experiences. Reconciling old schemas with new experiences requires a conceptual change, in which the learner either rejects the new experience outright or incorporates the new experience in one of three ways: rote memorization, conceptual exchange, or conceptual capture (Hewson, 1981). Science teachers are tasked with getting students to abandon misconceptions in favor of ones that support an accurate understanding of science, yet some students, through rote memorization, can provide a teacher the answer he/she wants without reconciling their previous misconceptions (Llewellyn, 2014).

Piaget (McLeod, 2015) also established four developmental stages for the reasoning process. An understanding of the sensorimotor and preoperational stages is important for parents and early educators but for middle school educators, the concrete operational and formal operational stages are most applicable. In a seventh-grade classroom, it is likely that teachers will have students in both stages. Those in the concrete operational stage can form logical thoughts in which they can think things out rather than always having to physically manipulate something to make meaning. For those students who have progressed into the formal operational stage, they have abstract thoughts and can test hypotheses.

Lev Semyonovich Vygotsky (Llewellyn, 2014) built on the idea that experiences with materials shape our learning by stating that social experiences contribute to learning as language has a major role in mental development. Students must have opportunities to manipulate materials while engaging in social interactions with their peers or nearby adults about those manipulations.

The constructivist theory, as shaped by Kant, Vygotsky, Dewey, Piaget, and Kuhn, have implications in the modern science classroom. Based on Dewey's beliefs, instruction should be shaped by students' prior knowledge and experiences and students should have opportunities to re-shape and build their understandings by working with materials, their peers, and teachers (Llewellyn, 2014). Piaget makes an argument for active and engaging experiences in which students have opportunities to test and challenge their presently held theories before teachers introduce vocabulary so students can first construct their understanding of phenomenon (Llewellyn, 2014). Vygotsky suggests that students' experiences in the classroom should be challenging enough that they can achieve them but only with some support and interaction with their peers and teacher so there is an opportunity for language to shape their mental development (Llewellyn, 2014). The 5E Learning Cycle provides an inquiry-based structure to achieve the educational needs identified by the constructivist theory.

Inquiry-based Learning and the 5E Learning Cycle

The goal of an inquiry-based teacher is to create an environment and opportunities for students to engage in inquiry. The Exploratorium in San Francisco states that:

> Inquiry is an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and testing those discoveries in the search for new understanding. Inquiry, as it relates to science education, should mirror as closely as possible the enterprise of doing real science ("What Is Inquiry?", paragraph #1).

One way to engage students in inquiry is to utilize the 5E Learning Cycle. Despite three decades of pre-service teacher training about the Learning Cycle, it is still an underutilized teaching strategy in elementary classrooms (Settlage, 2000). This is unfortunate as multiple studies suggest that the 5E Learning Cycle is an effective way to improve student learning in science. For example, in a study of 8th grade science students ($N = 101$) in the 5E treatment group had greater gains from a pre- and post-test about photosynthesis and respiration than students in a conceptual change text group or a control group who received no treatment but traditional teacher-led instruction about photosynthesis and respiration (Balci, Cakiroglu, & Tekkaya, 2006). When using the 5E

Learning Cycle to teach high school students about cells, student motivation and engagement increased by using the inquiry-based approach (Wilder & Shuttleworth, 2005).

Like the constructivist theory, the 5E Learning Cycle was shaped by many contributors and philosophies. Bybee and colleagues were especially influenced by Johann Friedrich Herbart, John Dewey, the Heiss, Obourn, and Hoffman Learning Cycle, and the Atkin-Karplus Learning Cycle (Bybee et al., 2006). An expansion of the 5E Learning Cycle to a 7E Learning Cycle has been suggested, but for the purposes of this action research project, the more widely utilized 5E Learning Cycle was used (Eisenkraft, 2003).

The 5E Learning Cycle's five stages guide students through the inquiry process: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). A description for each stage of the 5E Learning Cycle is included below (Table 1).

Table 1

Summary of the BSCS 5E Instructional Model Phase (Bybee et al., 2006, p. 3).

Phase	Summary
Engagement	The teacher or a curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities.
Exploration	Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.
Explanation	The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives.

Long-term Learning of Science Concepts

A goal of education is not short-term memorization of facts but long-term learning of important concepts. For this reason, retention of science concepts on 5E Learning Cycle units versus non-5E Learning Cycle units was compared to examine differences in science concept retention. A variety of studies suggest that inquiry-based learning can improve students' retention of scientific content across age groups. In a small study of fifth graders ($N = 26$), students who self-generated examples during a three-week unit on energy demonstrated a greater ability to recall those concepts six-months later than those students who did not self-generate examples (Gorrell, Tricou, & Graham, 1991). The Exploration and Elaboration stages of the 5E Learning Cycle present opportunities for students to self-generate examples so hopefully similar improvements in retention will be noted in this action research project. In another study of 24 tenth-grade students, a re-testing window of four months generated mixed results regarding students' retention of nature of science concepts from 5E Learning Cycle units on genetically modified foods and water fluoridation (Khishfe, 2015). A study of college introductory engineering statistics students demonstrated that students who worked on group projects with cooperative learning scored higher on an immediate post-test and a delayed post-test eight months later than those students receiving a traditional lecture-based delivery of the same content (Kvam, 2000). The re-testing window for this action research project was shaped in part by capstone deadlines, so I was not able to replicate delays of four to eight months like the studies detailed above. Instead I delivered the delayed post-unit assessments four weeks after the completion of each unit. Using the same four-week delay for each delayed post-unit test increased the validity and reliability of my results when examining students' retention of content from each of the four units. Comparing the impacts on long-term learning between the 5E Learning Cycle units and the non-5E Learning Cycle units proved very interesting and will be discussed later in this paper.

Implications for Teachers Implementing the 5E Learning Cycle

The third question addressed within this action research project was "How does implementing the 5E Learning Cycle impact me as a teacher?" A possible prediction of impact was highlighted in a study of 25 elementary teachers participating in an ongoing science in-service designed to help the participants

> understand: (1) that science is a search for knowledge and not only the knowledge, (2) that teaching science as a search for knowledge will lead students to construct their own knowledge about the world around them, and (3) how to develop a curriculum (learning cycles) which represents science, allows their students to experience science as a search for knowledge, and is compatible with their students' learning abilities (Marek & Methven, 1991, p. 42).

Study findings indicate that those teachers involved in the in-service improved their ability to use the 5E Learning Cycle and their students showed greater gains in conservation reasoning than the students of 25 similar teachers who did not participate in the in-service (Marek & Methven, 1991). Like the study detailed above, a goal of this action research project was to improve competency with inquiry-based teaching strategies. The Inquiry Through Science & Engineering Practices and Evaluation & Measurement courses through Montana State University's Master of Science in Science Education (MSSE) program provided a much more intensive exposure to inquiry-based teaching and the 5E Learning Cycle than the in-service program described in the study above. As a result, I believe my competency and comfort in utilizing inquiry-based teaching strategies improved significantly. I utilized the 5E Inquiry Lesson Plan Version 2 Rubric (Goldston, Dantzler, Day, & Webb, 2013) to monitor my increased competency with implementing the 5E Learning Cycle during the action research project. Goldston et. al's rubric went through extensive field testing which greatly increases the reliability and validity of the data collection tool. I also used the rubric to self-score the two 5E Learning Cycle units that were implemented and asked a colleague, Mark Rochin, to use the same rubric to critique the lessons as well. Those results will be discussed later in this paper.

METHODOLOGY

Treatment

My action research project spanned four units during parts of the second, third and fourth quarters of the 2017-2018 school year. Two of the units were conducted using the 5E Learning Cycle (Table 1 above) and served as the treatment units. Two other units were conducted using more traditional teaching practices and were the non-treatment units. The main distinction between the two unit styles dealt with teacher delivery of content information; for the 5E units, students first had the opportunity to experience the content or science phenomenon in some way before content vocabulary, main concepts, etc. were introduced whereas with the more traditional teaching style, the content and vocabulary were front loaded in the instructional sequence. Table 2 compares the 5E and non-5E units and the data collection tools and sequence utilized for each unit. All six sections of life science participated in the classroom research project and a comparison group was not needed as all students were exposed to two treatment units and two non-treatment units to use for comparison. The ultimate goals of the action research project were to hone my skills as an inquiry-based teacher and to gauge the impact of the two teaching styles on student learning and retention.

Table 2
A Comparison of 5E Learning Cycle versus Non-5E Learning Cycle Units

Non-5E Units (non-treatment) Instrumentation	5E Units (treatment) Instrumentation
• Use my existing lesson plans to guide instruction • Administer pre-test • Students design pre-unit concept map—evaluate with student self-assessment rubric and teacher assessment rubric • Teach unit lessons, using teacher self-reflection form throughout • Imbed performance assessments within the unit when appropriate • Upon completion of the unit's instruction, students make changes to their pre-unit concept map and again use the self-assessment and teacher assessment rubrics • Upon unit completion, students complete Student Feedback Form • Administer post-test • Administer delayed post-test (~4 weeks later)	• Use 5E lesson plan template to design instruction • Administer pre-test • Students design pre-unit concept map—evaluate with student self-assessment rubric and teacher assessment rubric • Teach unit lessons, using teacher self-reflection form throughout • Imbed performance assessments within the unit when appropriate • Upon completion of the unit's instruction, students make changes to their pre-unit concept map and again use the self-assessment and teacher assessment rubrics • Upon unit completion, students complete Student Feedback Form • Administer post-test • Conduct student interviews (after they have received one non-treatment and one treatment unit) and again after the next pairing of a non-treatment/treatment unit. • Administer delayed post-test (~4 weeks later) • Administer essential vocabulary progress check (which includes terms from non-treatment and treatment units) at least twice throughout the four-unit time span

Implementation of the classroom research project started with a non-treatment unit about Change Over Time that was taught using more traditional science teaching methods—I introduced the content which students then applied to various activities and then student learning was assessed. Next students participated in a 5E Learning Cycle unit about Adaptations and Biomimicry that was based on an 5E Learning Cycle lesson plan from *Science Scope* (Nicholas, 2015). We then transitioned to our Human Body unit with a traditional (non-treatment) unit about the levels of organization in the human body (cell, tissue, organ, organ system, organism). This was followed by a second treatment unit about the nervous system that was modeled after the 5E Learning Cycle lesson presented on the Better Lesson Plans website (Cerezo, 2018). By using two existing and vetted 5E Learning Cycle units, I increased the fidelity to which I implemented the 5E Learning Cycle with my students.

Timeline

Table 3 shows the time frame in which the four units were implemented. The first unit started mid-February and the fourth unit ended mid-April. Delayed post-tests extended beyond that time by four weeks.

Table 3
Implementation Timeframes for Treatment and Non-Treatment Units

Unit	Unit Type	Approximate Dates
Genetics—Changes Over Time (Mutations and Natural vs. Artificial Selection)	Non-5E (non-treatment)	February 12-23, 2018*
Adaptations and Biomimicry	5E (treatment)	February 26-March 13, 2018*
Human Biology—Levels of Organization	Non-5E (non-treatment)	March 14-23, 2018*
Human Biology—Nervous System	5E (treatment)	March 26-April 12, 2018*

*Delayed post-test 4 weeks after the completion of each unit

Data Collection Instruments

Most of the data collection tools were used to collect data on students' learning and retention of science content and concepts for all four units. Remaining data collection tools were used to assess the impact of the 5E Learning Cycle on me as a teacher. Table 4 shows the data collection tools used to address each sub-question.

Table 4
Quantitative and Qualitative Data Collection Tools

Sub-question	Data Collection Tools		
How does the 5E Learning Cycle impact students' learning of science concepts?	Comparison of pre- and post-test results (5E and non-5E)	Performance assessment results (5E and non-5E)	Comparison of pre- and post-concept maps • student self-assessment rubric • teacher-assessment rubric (5E and non-5E)
How does the 5E Learning Cycle impact students' retention of science concepts?	Comparison of post- and delayed post-test results (5E and non-5E)	Essential Vocabulary Progress Checks (5E and non-5E)	Student interviews (5E and non-5E)
How does implementing the 5E Learning Cycle impact me as a teacher?	Lesson Plan Template (5E only)	Science Learning Cycle Lesson Plan Rubric (Goldston, Dantzler, Day, & Webb, 2013) (5E only)	• Self-reflection form (5E and non-5E) • Student feedback survey (5E and non-5E)

The appendices include a copy of nine of the data collection tools: Tests (Appendix A), Performance Assessment Rubrics (Appendix B), Concept Map Rubrics (Appendix C), Essential Vocabulary Progress Check (Appendix D), Student Interview Questions (Appendix E), the 5E Learning Cycle Lesson Plan Template (Appendix F), the 5E Learning Cycle Lesson Plan Rubric (Appendix G), the Self-Reflection Form (Appendix H), and the Student Feedback Forms (Appendix I). The Concept Map Rubrics (Appendix C) were modeled after rubrics utilized in three previous MSSE capstone projects, one of which was used in a fourth grade mathematics classroom (Cook, 2012), another in a middle school earth and space science class (Magonigle, 2011) and the third in a high school physics course (Sumner, 2014). Two of the three capstone authors modeled their rubrics after ideas suggested in *Learning How to Learn* (Novak & Gowin, 1984). Given that the development of my rubrics was informed by four other similar rubrics which were utilized in a variety of classrooms, this enhances the validity and reliability of the instruments. I also piloted, and slightly modified, both the student self-assessment and teacher assessment rubrics prior to the treatment period. This gave students practice developing and assessing their concept maps as well as ample opportunities for me to practice and refine the teacher evaluation prior to the official classroom research project.

The Essential Vocabulary Progress Check (Appendix D) was utilized twice leading up to the action research project. This proved especially valuable as results the first time indicated that the special education version was overaccommodated, something that was rectified before using the tool again. Appendix D includes the matching definitions portion of the Essential Vocabulary Progress Check along with the word bank that was provided for students receiving general education instruction and those receiving special education instruction (The labels indicating general education and special education versions were removed on copies provided to students.). Appendix D also includes the multiple-choice comprehension portion of the Essential Vocabulary Progress Check and the student answer sheet. Each time this data collection tool was utilized, the order of the questions was scrambled to decrease the chances of cheating or memorization. After completion of all four units, the Essential Vocabulary Progress Check was used again to examine students' retention of key terms from the four units.

Student Interview Questions (Appendix E) were designed to test students' long-term retention of science concepts following each of the four units. Two MSSE cohorts provided feedback on the level of difficulty for the Student Interview Questions and felt that the questions from each of the four units were at similar cognitive levels. All four questionnaires were reviewed by my administrator and Montana State University's Institutional Review Board prior to the onset of the classroom research project. This resulted in an Informed Consent Exemption from Principal (Appendix J) and an Institutional Review Board Exemption (Appendix K).

Development of the Self-Reflection Form (Appendix H) was shaped by ideas shared by MSSE colleagues and feedback they provided about earlier versions of the form. The Student Feedback Form (Appendix I) was designed to do some member checking by my students of how they perceived me during the four units. The questions asked of students mirrored the same ones I reflected on each day on the Self-Reflection Form. The data from the two sources (Appendix H and I) will be used to help answer the sub-question "How does implementing the 5E Learning Cycle impact me as a teacher?"

Research Sample

Except for the student interviews, data was collected from all 128 seventh-grade life science students at Polson Middle School in Polson, Montana. The six classes met each day for approximately 50 minutes per school day in classes that ranged from 18 to 26 students per class. The seventh-grade class had slightly more females than males with

69 female students (53.9%) and 59 male students (46.1%). More than half of the students received assistance in obtaining school lunches: 64 (50%) of the students received free lunch and 14 (11%) received lunch at a reduced price. Their ages ranged from 11 to 14 years though the majority were 12 or 13 years old. Though the rural school district is located within the Flathead Indian Reservation, 75 students (58.5%) self-identified as white non-Hispanic and 51 students (39.8%) self-identified as American Indian/Alaskan Native. The Hispanic/Latino and Asian American ethnic groups were identified by one student each (0.8%). The majority of the students received general education instruction but there were 14 students (10.9%) who received special education accommodations and 2 students (1.6%) who received services through a 504 plan. Eleven students (8.6%) were identified as gifted learners, but not all were currently enrolled in any formal gifted education services during the school day.

Attendance and grade data is based on third quarter when most of this classroom research project took place. The average number of days missed third quarter by my students was 5.12 days. This amounts to an average of over twenty days of school missed per student over the course of four quarters, something that can be attributed to a lack of a district attendance policy, weak Montana laws about school attendance, and the challenges of a geographically large and low-income school district with very few public transportation options beyond scheduled school bus routes. Figure 1 shows that there is a wide range in the number of days missed per student third quarter.

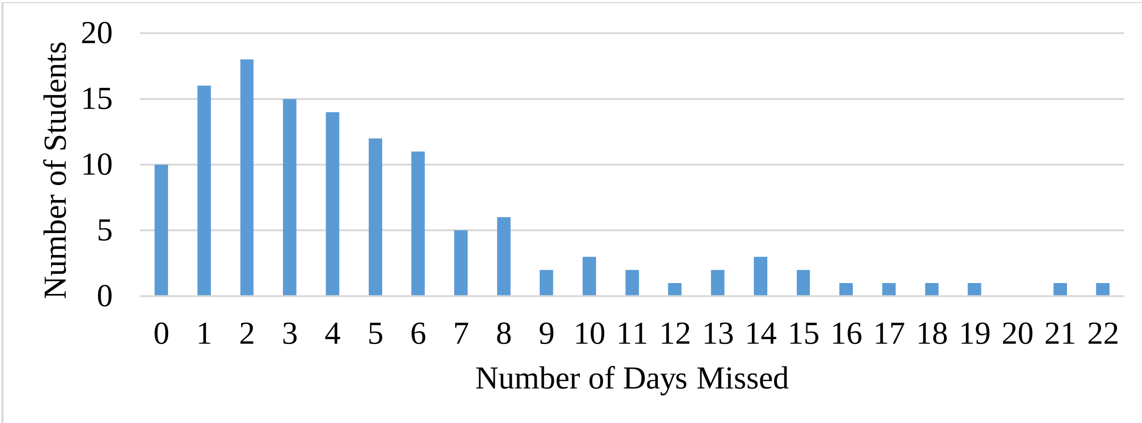

Figure 1. Student attendance third quarter, (*N* = 128).

Despite high absenteeism by some students, my students' life science grades are fairly high (Figure 2). Four of my 128 students are not accounted for in Figure 2 as they enrolled at our school too late into the quarter to accurately assign a third quarter grade. Generally high third quarter life science grades can be attributed in part to a twice weekly intervention in which any students with Ds or Fs are assigned to work with classroom teachers on missing work, re-teaching, etc. Students without any classes with Ds or Fs get to choose from a variety of fun and enriching activities during that time which motivates many students to keep their grades up.

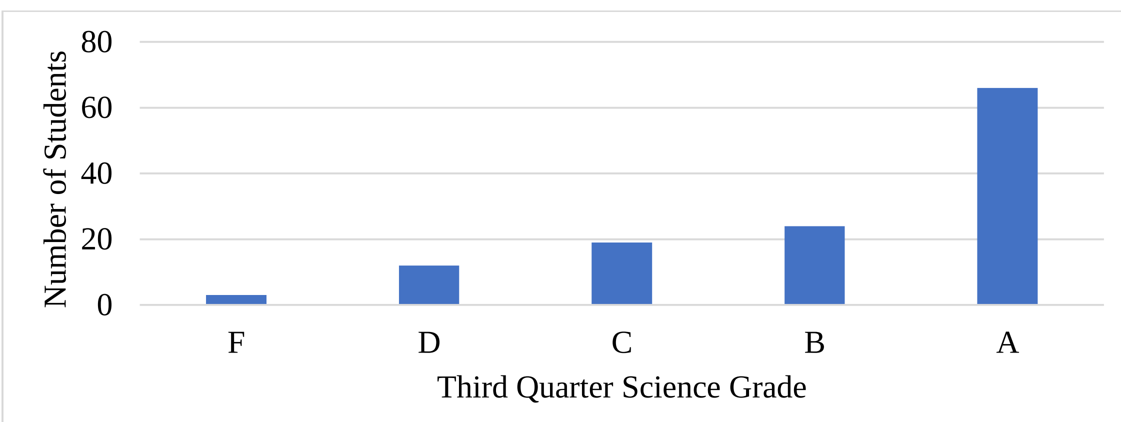

Figure 2. Final third quarter life science grades, (*N* = 124).

When conducting student interviews, students were sampled from my second, third, sixth, and seventh period classes as at least one other adult was present who could help with supervision of other students while I conducted interviews. I used a stratified randomly sampling as I selected two students from each grade band (A, B, C, D, and F) for a total of ten students each time interviews were conducted. The survey questions were reviewed in advance by my administrator and Montana State University's Institutional Review Board, both of which approved of this research and of the interview questions used in the classroom (Appendixes J & K).

DATA AND ANALYSIS

Impact on Student Learning

To answer the sub-question "How does the 5E Learning Cycle impact students' learning of science concepts?" three data sources were used: pre- and post-unit tests, performance assessments, and pre- and post-unit student generated concept maps. For all three data collection tools used to answer this first sub-question, data was grouped for the two types of units (5E versus non-5E) to synthesize the data for the reader.

Pre- and Post-Unit Tests

Appendix A includes an assortment of the unit tests. Pre-, post-, and delayed post-test versions were all slightly modified to prevent student memorization or academic dishonesty. When evaluating the pre- and post-unit scores, I used data only from those students who completed the pre- and post-unit tests associated with each of the four units. Many factors caused students to have missing data. Throughout the classroom research project several students moved into or out of our school or had extended absences which resulted in an incomplete data set for them so I eliminated their test scores from my analysis. Several students were absent on pre-test days and I did not want them miss classroom instruction in favor of the pre-test so I exempted them from the pre-test, further reducing my sample size of students with a complete data set. I also had 35 pre-tests on which a student scored the full 10 points, which meant the normalized gain formula could not be applied to their data as it would require dividing by zero. These reasons for incomplete data sets resulted in 77 of my 128 students with a complete and useable pre- and post-unit test data set. For those 77 students, I used the normalized gain score formula (1) to quantify how much their test scores improved for each of the four units.

$$\frac{\text{(post-test score – pre-test score)}}{\text{(total points possible – pre-test score)}} \qquad (1)$$

I then calculated their average normalized gain scores for each of the unit types, 5E versus non-5E, before using Microsoft Excel to generate box and whisker plots of the average normalized gain scores. Doing so revealed six outliers which I excluded from my further data analysis. All six of the outliers had average normalized gain scores below -0.4167, indicating that on at least one of their post-tests, they did more poorly than on their pre-test. Three of the six outliers had multiple absences during the action research project—two of them missed class four times, the other eight times. The three remaining outliers' possible reasons for a decline on a post-test is a bit more unclear. One of the students receives services through special education. Another outlier had high pre-test scores to begin with and a drop of just one point between the pre-test and post-test had a substantial impact on his normalized gain score yet his final scores were all B's and higher. The final outlier missed only two days during the classroom research project and had a lower post-test score on only one unit. He missed class the day students took that unit's post-test. Because he had to complete the test on his own time before school and not during class, I suspect he rushed to get back to unstructured time with his friends before school.

To determine if there was a statistically significant difference between the average normalized gain scores for the 5E and non-5E units, I utilized the Wilcoxon signed rank test. This non-parametric test was selected because the average normalized gain scores for the 5E units were skewed left. The test generated a Z-value of -5.0107 which is statistically significant at $\alpha = 0.05$. Figure 3 shows the box and whisker plots of the average normalized gains scores for each unit type. The normalized gain score average for the 5E units was 0.3165 whereas the non-5E units average score was 0.5254. Though normalized gain scores between 0.3 and 0.7 indicate medium growth and both scores fell within that range, the non-5E units had the highest average normalized gain scores. Based on a comparison of the pre-unit and post-unit tests, the non-5E units resulted in greater student gains based on the Wilcoxon signed rank test, Figure 1, and the normalized gain scores unit averages.

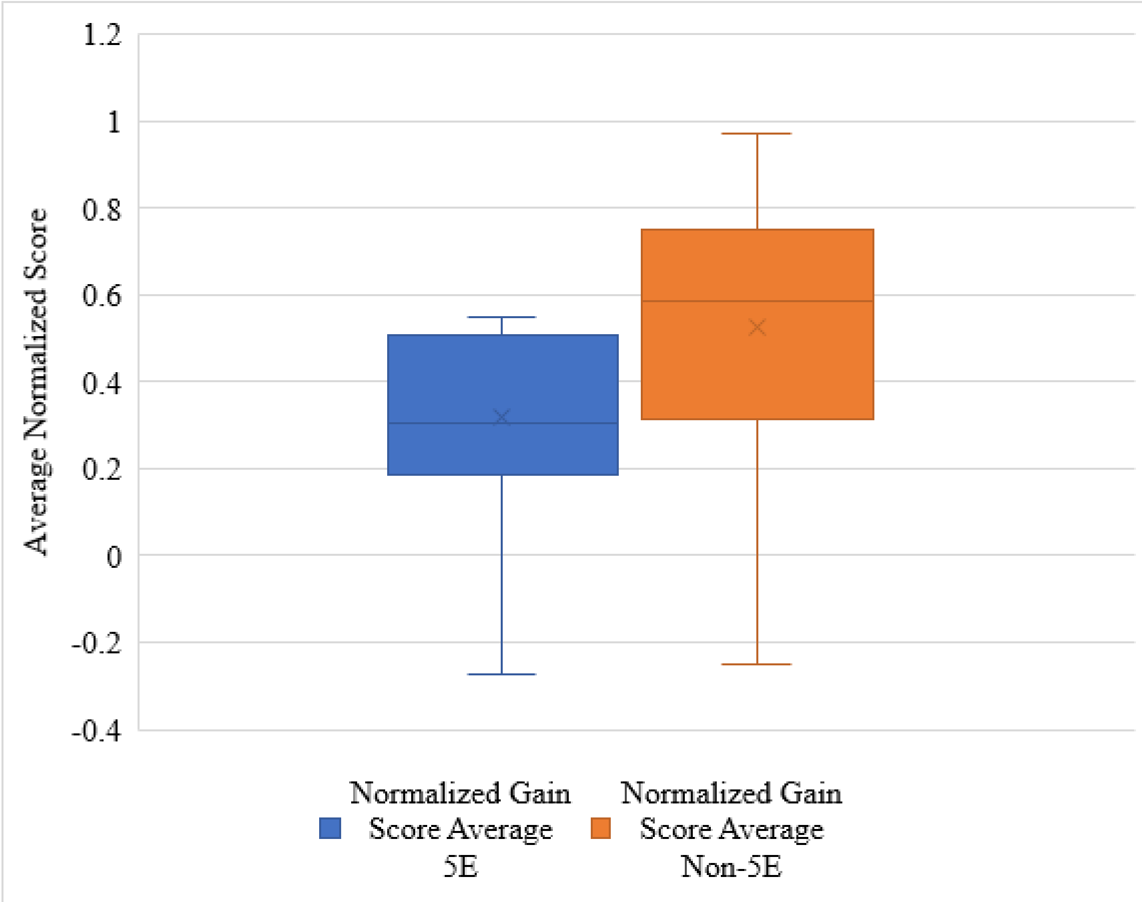

Figure 3. Average normalized gain scores for 5E versus non-5E units, (*N* = 71).

Though it appears that the non-5E units resulted in greater gains, at least on test performance, than 5E units, I also wanted to ensure that there was a statistical difference in students' scores between pre- and post-units tests all four units to document student learning. Because some of the pre- and post-unit test scores were not normally distributed, I again used the Wilcoxon signed rank test to test for significance. This time, students who earned full points on the pre-test were included in the analysis, resulting in a sample size of 112 students. Doing so generated the information displayed in Table 5 which when coupled with the box and whisker plots of pre- and post-test scores (Figure 4) indicates that all four units resulted in student learning. Except for the Changes Over

Time non-5E unit, the overall range of student scores and the middle two quartile boxes of the box and whisker plots decreased, suggesting that the 5E treatment (and for one non-5E treatment unit) the intervention resulted in student learning and closing the gap between the lowest and highest scores on the pre-test. For the Changes Over Time unit, the ranges stayed the same but shifted upward slightly indicating there was student learning but not the closing of the gap.

Table 5

Wilcoxon Signed Rank Test Results for Analysis of Pre- and Post-Unit Tests

Unit	Type	Z-value	Statistically significant at $\alpha = 0.05$
Adaptations & Biomimicry	5E	-7.9494	Yes
Nervous System	5E	-5.6685	Yes
Changes Over Time	Non-5E	-8.5671	Yes
Levels of Organization	Non-5E	-6.7614	Yes

Note. (*N* = 112).

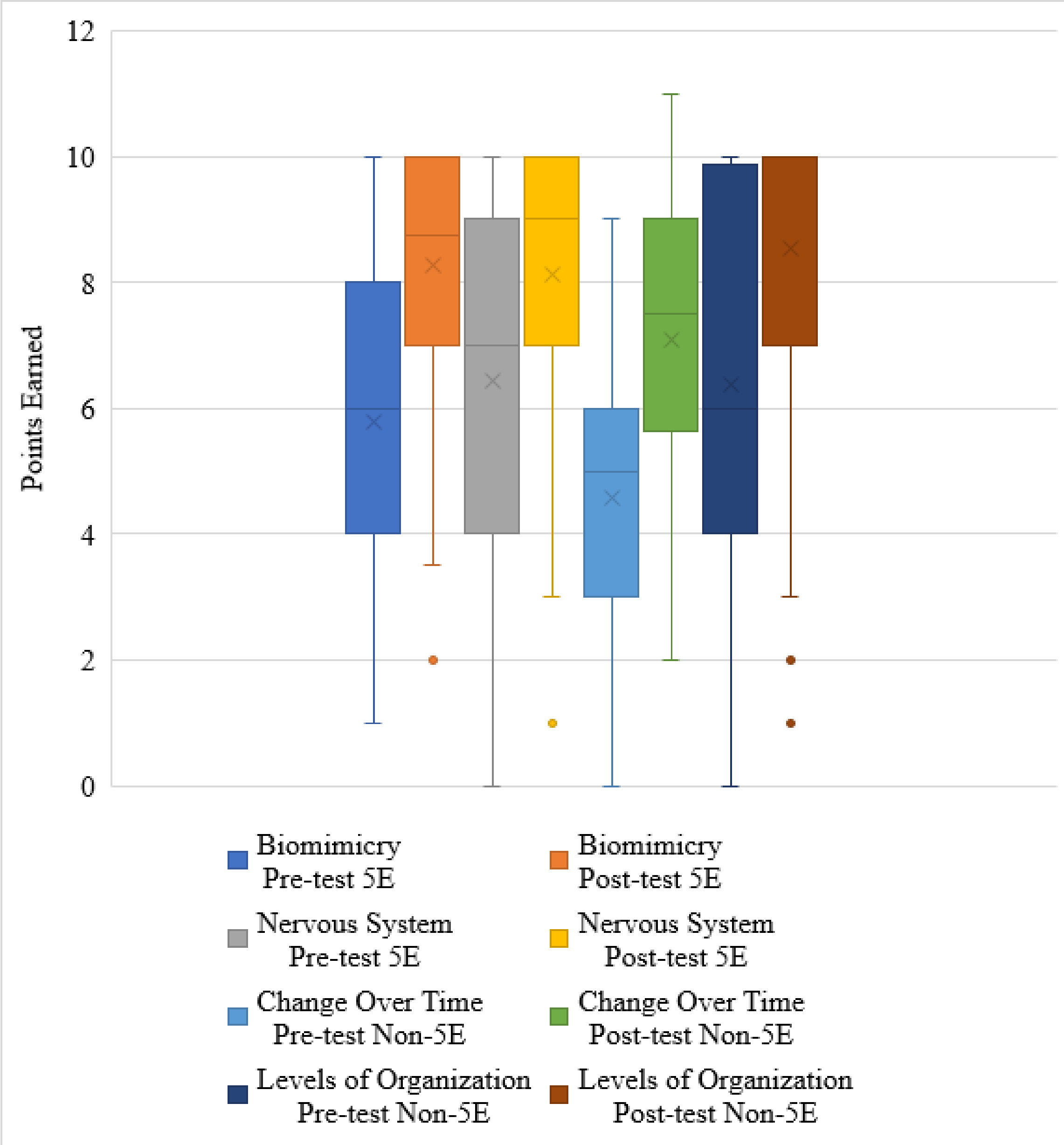

Figure 4. A comparison of each unit's pre- and post-test scores, (*N* = 112).

Next, I examined those students' whose scores fell one or more standard deviations above or below the average score using the numbers in Table 6.

Table 6

Average and Standard Deviation Scores for Normalized Gain Scores

	5E Units	Non-5E Units
Average Difference	0.317	0.525
Standard Deviation	0.205	0.287
Score Considered < 1 Standard Deviation Below Average	0.112	0.238
Score Considered > 1 Standard Deviation Above Average	0.522	0.812

Note. (*N* = 71).

From there, the distribution of students receiving general education, special education, gifted education, and 504 education services in the general population was compared to the groups substantially above and below the normalized gain scores averages in Table 7.

Table 7

Distribution of Students with Normalized Gain Scores Below Average

Instructional Delivery	General Population	5E Learning Cycle	Non-5E Learning Cycle
General Education	78.9%	66.7%	90.9%
Special Education	10.9%	33.3%	9.1%
Gifted Education	8.6%	0%	0%
504	1.6%	0%	0%

Note. (*N* = 71). (5E *n* = 12 students below one standard deviation). (Non-5E *n* = 11 students below one standard deviation).

These results suggest that the 5E Learning Cycle may present greater challenges for students receiving special education services as they are overrepresented in the population of students who fell one or more standard deviations below the normalized gain score averages. With non-5E Learning Cycle units, their representation within the group is much closer than that of the general population with just a 1.8% difference.

An analysis of students one or more standard deviations above the mean provided the data for Table 8.

Table 8
Distribution of Students with Normalized Gain Scores Above Average

Instructional Delivery	General Population	5E Learning Cycle	Non-5E Learning Cycle
General Education	78.9%	78.6%	100%
Special Education	10.9%	7.1%	0%
Gifted Education	8.6%	14.3%	0%
504	1.6%	0%	0%

Note. (N = 71). (5E n = 14 students above one standard deviation). (Non-5E n = 14 students above one standard deviation).

While the results for the 5E Learning Cycle units are diverse, it is interesting that all 13 students who scored one or more standard deviations above the mean for the non-5E units were general education students. This suggests that perhaps non-5E instructional methods best meet the needs of most students.

I also was curious about the impact of the treatment units on students who earned a third quarter letter grade of D or F to see if there was a measurable difference on their learning between 5E Learning Cycle units and the non-5E units. My hope in analyzing the data of these students was that a clear winner would be revealed between 5E or non-5E instruction for helping struggling students. Of the fourteen students who had third quarter grades below 70%, only three had a complete data set for all four units. The group of 14 students missed an average of 10.2 days during third quarter which is almost double the average number of days missed third quarter by all of my seventh-grade students (5.12 days). Though the sample size is extremely small, I calculated the average number of points different between each pre- and post-unit test. Doing so generated an average number of points improved on 5E units of 1.15 points whereas the non-5E units showed slightly more average improvement with 2.18 points. This suggests that non-5E units may better help struggling students learn but the sample size and difference between averages (1.03 out of 10 possible points) are both so small that I am reluctant to make any strong statements based on those results. The group's high absenteeism also likely undercut both instructional methods' effectiveness for those 14 students.

Performance Assessments

Each of the four units implemented had a performance assessment (Appendix B) embedded within the unit. For the non-5E Change Over Time unit, students conducted an experiment that modeled natural selection in a mouse population and then analyzed their data. In the 5E Adaptations and Biomimicry unit, students created an invention that mimicked one or more of nature's solutions to a human problem they identified. For the non-5E Human Body: Levels of Organization unit, students participated in a structured class debate about one of Page Keely's assessment probes about what the human body is made of and then wrote a Claim-Evidence-Reasoning paper about which of the three student viewpoints represented in the probe was correct. In the 5E Nervous System unit, students conducted a lab in which they tested their reaction speed to visual, auditory, and tactile stimuli and then analyzed their data to draw conclusions. All four performance assessments had accompanying rubrics which students were introduced to prior to the start of each performance assessment.

Three of the four performance assessments were evaluated on a 16-point scale. The fourth one was on a 25-point scale. To allow for comparison between the four units, I converted the scores out of 25 possible points to scores out of 16 possible points to make for more seamless data analysis. Several students missed one or more of the performance assessments due to movement into or out of our school or substantial absences. This dropped the sample size for this analysis to 111 students. For those 111 students, their average performance assessments scores for each of the unit types, 5E versus non-5E was then calculated and then used to create a box and whisker plot of the results (Figure 5). Because the averages for both the 5E and non-5E units had roughly normal distributions, I then conducted a paired t-test. Doing so generated a t Stat = 3.5199. The critical value at 100 degrees of freedom is 1.984 which indicates that there is a statistically significant difference between the two data sets at $\alpha = 0.05$. The paired t-test results, Figure 5, and the fact that the 5E performance assessment average (12.35) is higher than the non-5E average (11.33), suggests that students performed better on performance assessments embedded within 5E units than those within non-5E units.

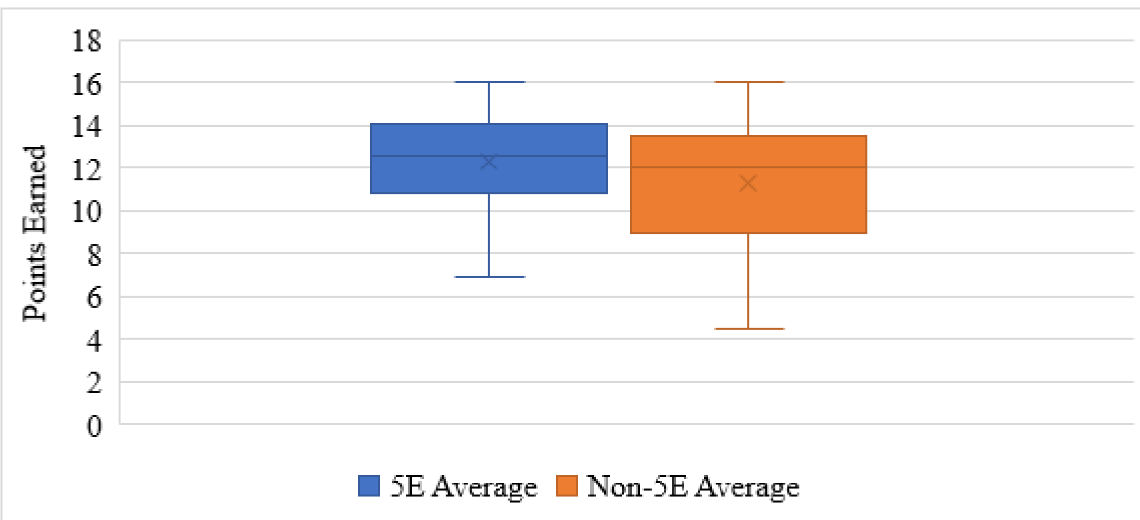

Figure 5. Average performance assessment scores on 5E versus non-5E units, (N = 111).

Identification of students who were one or more standard deviations above or below the performance assessment averages were based on the scores displayed in Table 9.

Table 9
Average and Standard Deviation Scores for Performance Assessments

	5E Units	Non-5E Units
Average Score	12.36	11.33
Standard Deviation	2.08	2.90
Score Considered < 1 Standard Deviation Below Average	10.28	8.43
Score Considered > 1 Standard Deviation Above Average	14.44	14.23

Note. (*N* = 111).

To try to predict what future students might struggle or excel on performance assessments associated with 5E Learning Cycle or non-5E Learning Cycle units, I examined the percentage of students above and below one standard deviation of the seventh-grade general population, generating Tables 10 and 11.

Table 10
Distribution of Students with Performance Assessment Scores Below Average

Instructional Delivery	General Population	5E Learning Cycle	Non-5E Learning Cycle
General Education	78.9%	85.0%	68.4%
Special Education	10.9%	15%	26.3%
Gifted Education	8.6%	0%	0%
504	1.6%	0%	5.3%

Note. (*N* = 111). (5E *N* = 20 students below one standard deviation). (Non-5E *N* = 19 students below one standard deviation).

Students receiving special education make up 10.9% of my seventh-grade student population but were 15% (5E) and 26.3% (non-5E) of the students who scored one or more standard deviations below the performance assessment average for each unit type. This implies that either students receiving special education are not learning at the same level as their peers during both the treatment and non-treatment units or that they were especially challenged by the performance assessments or a combination of the two.

Though 5.3% of the students below the standard deviation were receiving services through a 504, I am reluctant to make any assumptions about that as only one student accounted for the 5.3%. The wide variety of ways students can qualify for 504s is so broad that any generalizations about students with 504s, especially with such a small sample size, would be unfounded.

Table 11
Distribution of Students with Performance Assessment Scores Above Average

Instructional Delivery	General Population	5E Learning Cycle	Non-5E Learning Cycle
General Education	78.9%	77.8%	73.7%
Special Education	10.9%	5.6%	0%
Gifted Education	8.6%	16.7%	26.3%
504	1.6%	0%	0%

Note. (*N* = 111). (5E *N* = 18 students above one standard deviation). (Non-5E *N* = 18 students above one standard deviation).

Among students who scored one standard deviation or more above the performance assessment average, gifted learners are overrepresented whereas special education students are underrepresented. This suggests that students receiving special education services are more likely to struggle on performance assessments than their peers and may need additional accommodations or modifications to perform at the same level as their general education and gifted education peers. Students identified as gifted learners comprised a larger percentage of students scoring one or more standard deviations above the seventh-grade average for both unit types, but for the non-5E units, they accounted for 26.3% of the significantly above average scores and only 16.7% of the especially high scores for the 5E performance assessments. I believe this is largely attributed to the fact that no special education students had a score one or more standard deviations above the grade-level average on the non-5E units. This drove the percentage for gifted students up even higher for the performance assessments associated with non-5E units. Performance assessments, including 5E inquiry-based labs, are more demanding of students than traditional assessment methods like straightforward tests and quizzes which may account for why special education students were overrepresented in the group of students showing significantly below average scores and why they were underrepresented in the group of students showing above average performance assessment scores. I do not know that the differences between the 5E and non-5E performance averages representations are based on a large enough sample size to make assumptions about which instructional method is best for individual groups based on the performance assessment data collection tools alone.

Pre- and Post-Unit Concept Maps

To assess students' understanding of each unit, they generated pre- and post-unit concept maps after substantial coaching and practice on how to do so prior to the start of this classroom research project. Any students lacking data for one or more concept maps were eliminated from this data analysis as was one outlier—a student whose average number of points improved for the non-5E units was an outlier at 60.5. This created a sample size of 95. To measure the impact of the two teaching styles on students' learning, the difference between students' pre-unit and post-unit concept map rubrics (Appendix C) for each unit was calculated. Next the two 5E unit differences were averaged together as were the two non-5E unit differences. The two data sets were then evaluated using the paired t-test which generated a t Stat = 1.799 which is less than the critical value of 1.990 at 80 degrees of freedom, indicating the two data sets are not statistically different which is further supported by the box and whisker plots in Figure 6. Both the range and means are similar between the two data sets as are the placement of the middle two quartiles. The evidence of the pre- and post-unit concept map data suggests that there is not a significant difference in the amount of information students learned whether the 5E Learning Cycle was utilized or not.

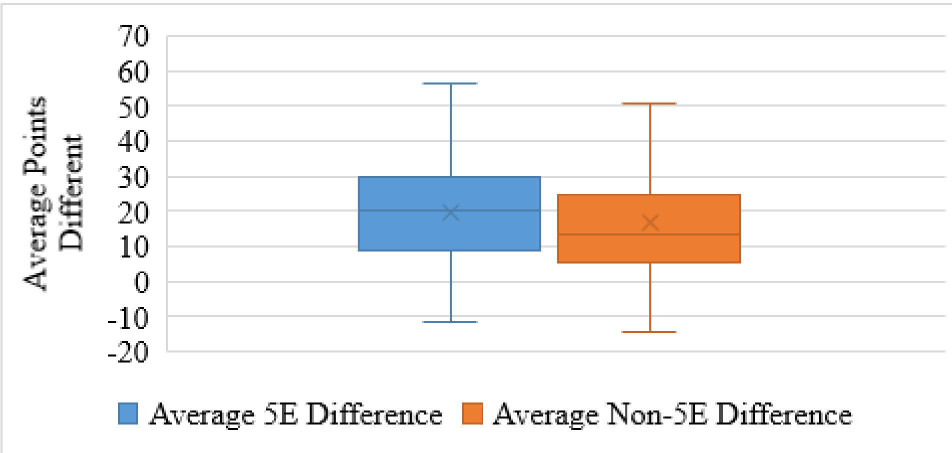

Figure 6. Average differences between pre- and post-unit concept maps, (*N* = 95).

Identification of students who were one more standard deviations above or below the average were based on the scores displayed in Table 12. It should be noted that this analysis does include the one outlier previously mentioned, bringing the sample size up to 96.

Table 12
Average and Standard Deviation Scores for Concept Maps Differences

	5E Units	Non-5E Units
Average Difference	14.87	15.03
Standard Deviation	19.69	16.97
Score Considered < 1 Standard Deviation Below Average	5	2
Score Considered > 1 Standard Deviation Above Average	35	32

Note. (*N* = 96).

To predict future students who might show significantly below or above average growth between their pre-unit and post-unit concept maps using the 5E Learning Cycle or non-5E Learning Cycle teaching methods, I compared the percentage of students above and below the standard deviation to the seventh-grade general population, producing Tables 13 and 14.

Table 13
Distribution of Students with Below Average Concept Map Growth

Instructional Delivery	General Population	5E Learning Cycle	Non-5E Learning Cycle
General Education	78.9%	68.4%	70.0%
Special Education	10.9%	26.3%	20.0%
Gifted Education	8.6%	5.2%	10.0%
504	1.6%	0%	0%

Note. (*N* = 96). (5E *N* = 19 students below one standard deviation). (Non-5E *N* = 9 students below one standard deviation).

Though students receiving special education compromise just 10.9% of the seventh-grade student population, they represented 26.3% (5E) and 20.0% (non-5E) of the students who scored one or more standard deviations below the average difference between pre- and post-unit concept maps. This implies that either the students receiving special education are not learning at the same level as their peers during both 5E Learning Cycle units and non-5E Learning Cycle units or that they struggled with the concept mapping or some combination of the two. Due to the nature of learning disabilities and for many special education students a struggle with abstract reasoning, I suspect it is likely a combination of the two but cannot say for sure without additional research. Though we practiced concept mapping as a class, in small groups, and with science content not part of the classroom research project, it is possible some of these students needed more practice with generating their own concept maps.

To scaffold those students who continued to struggle with concept mapping or who did not show substantial growth between pre- and post-unit concept maps, I generated an alternative concept map for each unit which incorporated the same words students were instructed to include in their own self-generated concept map and then had them complete that concept map. Over time, some students made the transition from needing the alternate concept map to generating their own concept map that showed growth. Other students required the alternate concept map for all four units. Students who often struggle with abstract thinking seemed most likely to struggle with the concept mapping process.

Table 14

Distribution of Students with Above the Average Concept Map Growth

Instructional Delivery	General Population	5E Learning Cycle	Non-5E Learning Cycle
General Education	78.9%	72.7%	88.2%
Special Education	10.9%	0%	0%
Gifted Education	8.6%	27.3%	11.8%
504	1.6%	0%	0%

Note. (N = 96). (5E N = 11 students above one standard deviation). (Non-5E N = 17 students above one standard deviation).

Of those students who scored one standard deviation or more above the average difference between pre- and post-unit concept maps, students identified as gifted learners comprised a substantially larger portion than they represent within the general seventh-grade population for the 5E Learning Cycle units. This suggests that the 5E Learning Cycle may be especially beneficial for gifted learners, though the difference could also be attributed or partially attributed to a higher likelihood of high-level abstract thinking for gifted learners than their peers.

I received feedback from several students that they liked the concept maps and that it was an effective studying tool for them. Other students were very happy when we completed the eighth and final official concept map of the classroom research project. Though they took a substantial amount of time to grade, I found that the concept maps gave me some of the best insights into student understanding, and in some cases misconceptions, of all data collection tools utilized for this project.

Impact on Student Retention

Answering "How does the 5E Learning Cycle impact students' retention of science concepts?" required three data sources: a comparison of post-unit and delayed post-unit assessments, Essential Vocabulary Progress Checks, and Student Interview Questions. When reasonable, data was grouped for the two types of units (5E versus non-5E) to synthesize the data.

Post- and Delayed Post-Unit Tests

Students took post-unit tests at the culmination of each unit and then repeated each unit's test four weeks later to compare the retention of content from 5E Learning Cycle units versus non-5E Learning Cycle units. The data set includes 108 students who took all four post-unit and delayed-post unit assessments. Because the distribution of some of the test results were not normal, the Wilcoxon Signed Rank Test was utilized to determine if there was a statistically significant difference between the non-parametric data sets (Table 15). Of the four units, only one unit had a statistically significant difference between the post-unit and delayed-post unit test: Change Over Time. I feel that this non-treatment unit was perhaps more intellectually demanding of students as many of the concepts of evolution are difficult for students to grasp. For example, I found that several students continued to think that individual organisms can choose to adapt, rather than realizing that adaptation is something that happens to an entire species due to new mutations and environmental pressures. There were also several students who knowing that the delayed-post unit test would not impact their science grade, responded to the short answer questions based on their religious beliefs and not the scientific theory of evolution. I was a little surprised not to hear from any of these students' parents during the Change Over Time unit. I did encourage students to talk with their families about the unit and shared with students about the reasons for the separation of church and state being written into our Constitution when students asked about creationism or brought up other misconceptions about evolution. Perhaps knowing the rationale behind what we were focusing on in science, the short duration of the unit, and my established rapport with families was enough to prevent parental concern or contact. I believe the difficulty of grasping the premises of the Change Over Time unit and the religious beliefs of some students accounts for the statistically significant different scores more so than the method of instructional delivery.

Table 15

Wilcoxon Signed Rank Test Results for Post- and Delayed Post-Unit Tests

Unit	Type	Z-value	p-value	Statistically significant at α = 0.05
Adaptations & Biomimicry	5E	-1.2875	0.1971	No
Nervous System	5E	-0.4155	0.6745	No
Changes Over Time	Non-5E	-1.9956	0.0455	Yes
Levels of Organization	Non-5E	-1.6784	0.0929	No

Note. (*N* = 108).

Though the results do not show an overall statistically significant difference between retention on 5E and non-5E units, I was pleased that on the four-week delayed post-unit tests, students generally retained the essential content associated with each unit. Box and whisker plots (Figure 7) show that student scores remained similar between the post-unit and delayed post-unit scores. One of my concerns when designing this action research project was that students might become apathetic on those data collection tools that would not impact their grade and not put forth their best effort. Though there were a few exceptions, I was very pleased that most of my students appeared to work to the best of their ability whether data collection tools would impact their science grade or not. I am especially appreciative of their hard work. I think some of what worked to my advantage was that early in the process, I started sharing a lot of the data with them and most were very interested in seeing their individual growth as well as how it stacked up against their class and grade-level peers. They are now quite good at interpreting box and whisker plots.

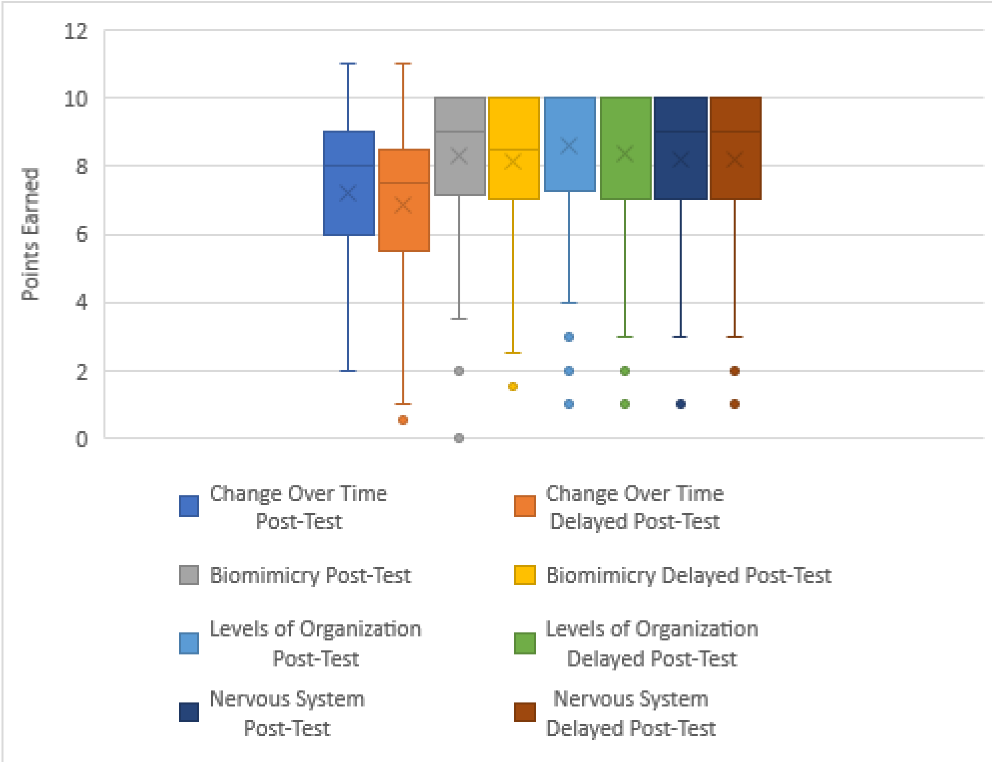

Figure 7. Post-unit and delayed post-unit test scores, (*N* = 108).

Though earlier analysis of students who earned Ds or Fs third quarter revealed a possible slight advantage for student learning based on non-5E instructional methods, I also wanted to examine the impact of the two unit types on student retention of content. For both unit types, I averaged the number of points changed between the post- and delayed post-unit tests. Doing so revealed that on 5E units, students improved an average of 0.71 points between the post-unit test and delayed post-unit test four weeks later whereas on the non-5E units, test scores dropped an average of -0.5 points. This suggests that perhaps the mental exercise that 5E Learning Cycle units require of students might result in better retention of content over time but due to the very small sample size and small difference between the two averages (1.21 points out of 10 possible points), I am reluctant to make a strong statement to that affect.

Essential Vocabulary Progress Checks

The Essential Vocabulary Progress Check (Appendix D), administered after completing all four units, allowed for item analysis for essential vocabulary terms associated with the four units during the classroom research project. A handful of students did not complete one or both portions of this data collection tool and were excluded from this portion of the data analysis. The purpose of the Essential Vocabulary Progress Check was to measure students' long-term retention of terms associated with both 5E and non-5E units. With just thirteen total terms associated with the four units (four terms from 5E Learning Cycle units, and nine terms from non-5E Learning Cycle units), formal statistical analysis was not feasible, but Figure 8 indicates that for both matching definitions and comprehension questions, students selected the correct answers at a higher percentage for terms associated with 5E units than for those terms associated with non-5E units.

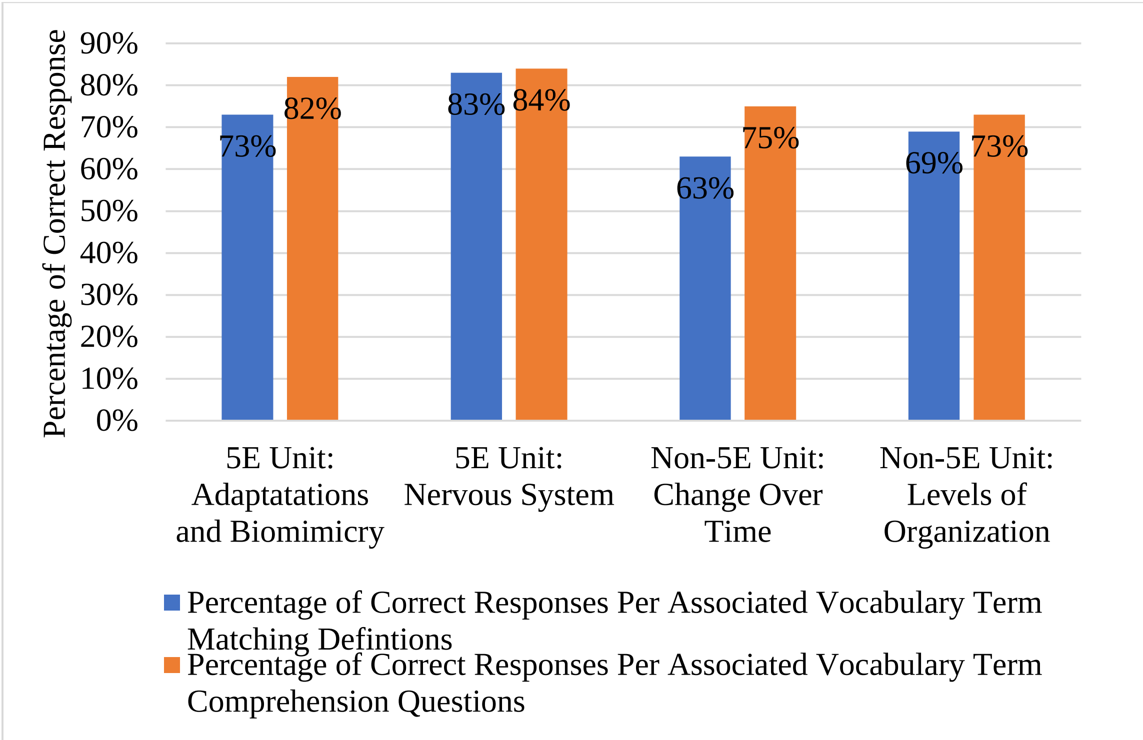

Figure 8. Correct response percentages for 5E and non-5E vocabulary terms, (N = 123 for matching definitions, N = 121 for comprehension questions).

Student Interview Questions

In another attempt to measure students' retention of content and concepts following the four units of this classroom research project, I conducted one-on-one interviews with students after the completion of two units—one non-5E and one 5E (Appendix E). While I set out to interview ten students each time, support staff was less available than I had anticipated due to state testing needs so that number was reduced. I also intended to test students from all five grade bands (A, B, C, D, and F) but on interview days, the D and F students were gone or had work they needed to complete that took precedence over participating in the interviews. The first interview cycle, addressing the Change Over Time and Adaptations & Biomimicry units, included six students. The second interview cycle, addressing the Levels or Organization and

Nervous System units, included five students, four of whom I interviewed during the first cycle. For the first interview cycle, I randomly selected students from the A, B, and C grade bands. For the second cycle, I first tried to re-interview those from the first cycle and then randomly selected one additional student. Interview questions and the rubric for scoring their responses can be found in Appendix C.

Though the sample size of seven students was too small for rigorous statistical analysis, it appears that students generally do about the same when recalling information from both 5E and non-5E units (Figure 9). There also does not appear to always be a direct correlation between a student's grade and their ability to recall or articulate scientific ideas. For example, Student #5 had the fifth lowest third quarter grade of the seven students interviewed yet his interview scores were close to the students holding the two highest third quarter grades of the interview group. This young man is often highly intellectually engaged during class discussions and activities but his follow through on assignments and organization is often not at the same level of his engagement.

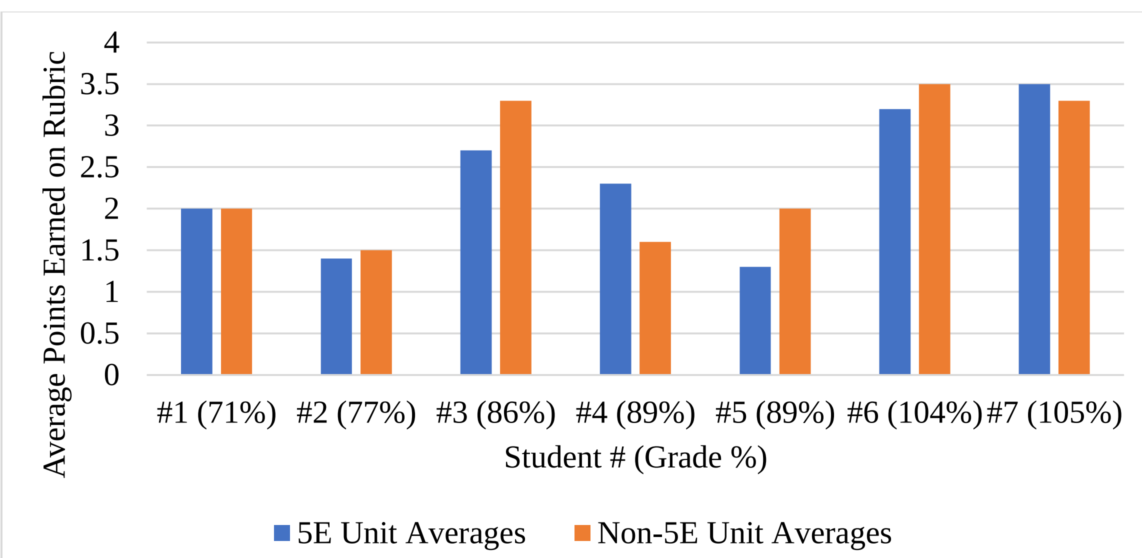

Figure 9. Students' average points earned during 5E and non-5E unit interviews, (*N* = 7).

The interview process was both enjoyable and helpful for me as it provided the opportunity to connect with students one-on-one and to reteach as needed and to answer student questions. For example, the interview revealed that Student #1 was confusing biomimicry with bioutilization which provided the opportunity for me to make distinctions between the two for him and then he gave me an accurate example of biomimicry after that intervention. Student #s 1, 2, and 4 had a hard time explaining what biomimicry was so I worked with them to break down the key parts of the word (bio-, and mimic) and they were then able to define the term biomimicry. Student #7 wanted to know more about brain tumors and so the interview gave us the opportunity to discuss that as well.

Impact on Teacher

To chronicle "How does implementing the 5E Learning Cycle impact me as a teacher?" I utilized the 5E Learning Cycle Lesson Plan Template and the Science Learning Cycle Lesson Plan Rubric for the two 5E units and the Self-Reflection Form and Student Feedback Form for all four units. The Self-Reflection and Student Feedback forms and rubric generated both quantitative and qualitative data whereas the lesson plan template provided qualitative evidence of my development as an inquiry-based teacher. When logical, data from the two 5E Learning Cycle treatment units was combined as was the data from the two non-treatment units.

Lesson Plan Template

When selecting instructional activities and resources for the 5E Learning Cycle units on Adaptations & Biomimicry and the Nervous System, I used the 5E Learning

Cycle Lesson Plan Template (Appendix F) to guide unit development. The template's inclusion of a description for each stage helped me ensure that I was including the necessary elements for each of the five stages. Interestingly, when designing the instruction for the two non-treatment units, I found that I had to be mindful of not inadvertently using instructional sequences or methods that were too similar to the 5E Learning Cycle. Participation in various inquiry-based professional development opportunities and the MSSE program has helped me to move my instruction more towards the inquiry approach and I had to take a step back from some of that to ensure there were adequate differences between the style of instruction for the treatment and non-treatment units. In reflecting on the two non-treatment units and conflicting results from the multitude of data collection tools from this classroom research project, I am not confident that my instructional methods in the treatment and non-treatment units were different enough. I was careful to avoid using the 5E Learning Cycle sequencing of Engage-Explore-Explain-Elaborate-Evaluate (Table 1), but some of the activities within the non-5E units embraced some of the same constructivist ideas that the 5E Learning Cycle is built upon. For example, in the non-5E Change Over Time unit, the Mouse Lab Performance Assessment (Appendix B), was an inquiry-based activity in which students discovered how environmental factors could lead to changes in a species over time. I could have avoided this "inquiry contamination" of my non-treatment units by simply telling students about different species that have changed over time and why, but that felt like too far a deviation from all I have learned during this MSSE adventure and would not have been true to my teaching style or what I believe is in the best interest of student learning.

<u>Science Learning Cycle Lesson Plan Rubric</u>

Both the Adaptations & Biomimicry and Nervous System 5E Learning Cycle units were assessed using the Science Learning Cycle Lesson Plan Rubric (Appendix G) by my science colleague Mark Rochin and myself. I did this to receive constructive feedback from a peer and to validate my own assessment of the two units. Mark will also be teaching some of the seventh-grade science sections next year so it gave him the chance to review the units to see if he wants to use them in the future. When comparing Mark's evaluation of the Adaptations & Biomimicry unit to my own, I found that we agreed on 17 of the 24 items, with him always being more generous on the scoring than myself; he rated 23 of the 24 items as excellent. The one area that we both marked the lesson "good" as opposed to "excellent" was in the Explain phase which evaluated whether the lesson "includes mixed divergent and convergent questions for interactive discussion facilitate by teacher and/or students to develop concept or skill." When posing questions to students, I try to include questions from a variety of different cognitive levels (recall, comprehension, application, analysis, and evaluation) but I need to be more mindful of intentionally incorporating both convergent and divergent questions within those various cognitive domains. In general, I feel that this lesson, whose development was guided by the *Biomimicry: The "Natural" Intersection of Biology and Engineering* article (Nicholas, 2015), was effective at introducing students to the idea of biomimicry and challenging them to come up with their own creative and research based biomimetic solutions.

In reviewing our assessment of the nervous system 5E Learning Cycle lesson plan, I found that we agreed on 23 of the 24 lesson criteria assessed. I felt that the list of materials was missing some items that I will add for next year and therefore reduced the score for "Materials list is present and complete" below that of Mark's score. Looking back on the unit, I feel that the nervous system 5E Learning Cycle unit, based on *You have a lot of nerves - an introduction to the nervous system* (Cerezo, 2018) was effective and look forward to using it again next year. I look forward to the opportunity to collaborate with Mark next year for our curriculum development. We plan to use both of 5E Learning Cycle units I implemented this year and will continue to tweak and improve them to best meet the needs of our diverse learners.

Self-Reflection and Student Feedback Forms

By comparing my daily responses on the Self-Reflection Form (Appendix H) to the four end of unit Student Feedback Forms (Appendix I), I validated my perceptions of how the 5E and non-5E teaching styles impacted me as a teacher. As evidence in Figure 10, both myself and my students were more likely to rate me favorable or neutral than negative for each of the five attributes (Table 16) the two data collection tools assessed. Doing this member checking with students' responses increased the validity and reliability of my responses.

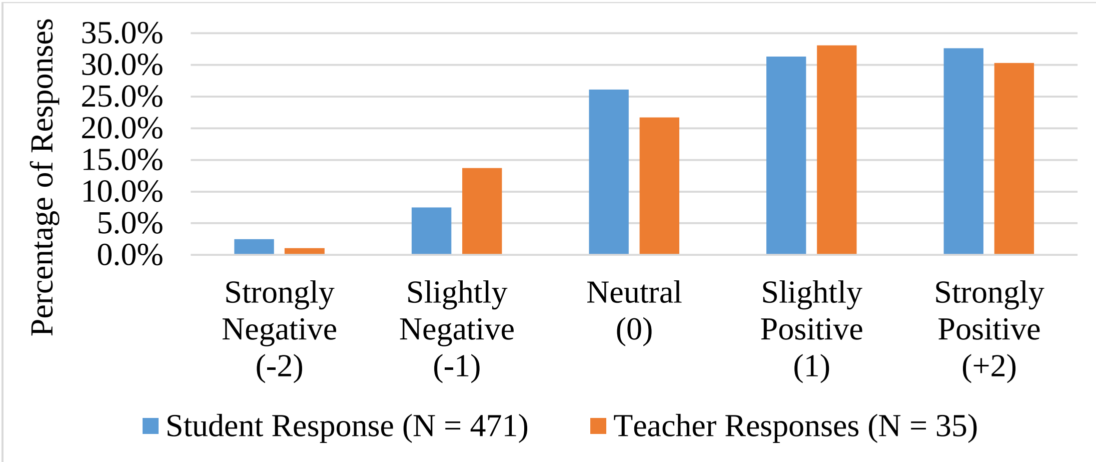

Figure 10. Self-Reflection and end-of-unit Student Feedback Forms results, (Student *N* = 471, Teacher *N* = 35).

The *N* values for Figure 10, require some explanation. My 128 students completed the Student Feedback forms 471 times, 228 times for the 5E units and 243 times for the non-5E units. I completed the daily Self-Reflection Form 35 times thus Teacher *N* = 35. The *N* values for Figures 11 through 14 are recorded in a similar manner.

Table 16
Attributes Assessed on Self-Reflection and Student Feedback Forms

Negative Attribute	Positive Attribute
stressed	relaxed
overwhelmed	encouraged
sluggish	energized
bored	curious
impatient	patient

In examining student and teacher responses for each of the five attributes individually, some interesting patterns emerged. When my stressed versus relaxed level was assessed (Figure 11), students were less likely to rate me as mildly stressed than I was for both 5E and non-5E units. On non-5E units, I was more likely to rate myself as slightly or strongly relaxed than I was on 5E units. This can be attributed to a greater comfort with the traditional, non-5E teaching methods and the level of frustration sometimes experienced during the Biomimicry Invention Project (5E) when technology glitches and a few sluggish or unmotivated groups resulted in stress. Days in which I rated myself mildly stressed or neutral, I wrote comments about the challenges of juggling the time demands of grading and analyzing all the data collection tools, the interruption of late school starts due to poor road conditions, and/or disruptions caused by multiple student absences. My stress level was less affected by the teaching style than it was by outside factors that influenced the classroom. During the 5E Adaptations and Biomimicry unit I noted that, "I'm so over the absences and trying to get students through so many data collection tools! When I build in time to work on old stuff either they aren't here or there is no sense of urgency from so many!" Similar comments were found in my notes from the non-5E units as well though. During the Change Over Time non-5E unit, I recorded that "Late starts are making staying on track with the action research project difficult. There were a lot of absences today due to late start/roads. Often the kids who need to be here most are not." Students seemed to reflect more on things outside the curriculum impacting my stressed versus relaxed levels as well. From one of the 5E units, a student from my largest class noted that "It's really hard to take care of a bunch of kids, including the ones that don't really listen." During a non-5E unit, a student mentioned that "I feel like she's always doing something so she has not the time to stress or be bored." Student perceptions are certainly interesting. Also, during a non-5E unit, a student from my largest and most challenging class marked me slightly relaxed (+1) and noted that "we have a big class with some kids that misbehave so it's a little stressful." My new favorite student remarked that, "I think that Mrs. Dalbey doesn't get lots of breaks and she deserves more breaks." One especially honest student referring to himself confessed that, "I can be very stressful." Overall student comments did not reveal any clear distinction between the 5E and non-5E units on my stressed versus relaxed level.

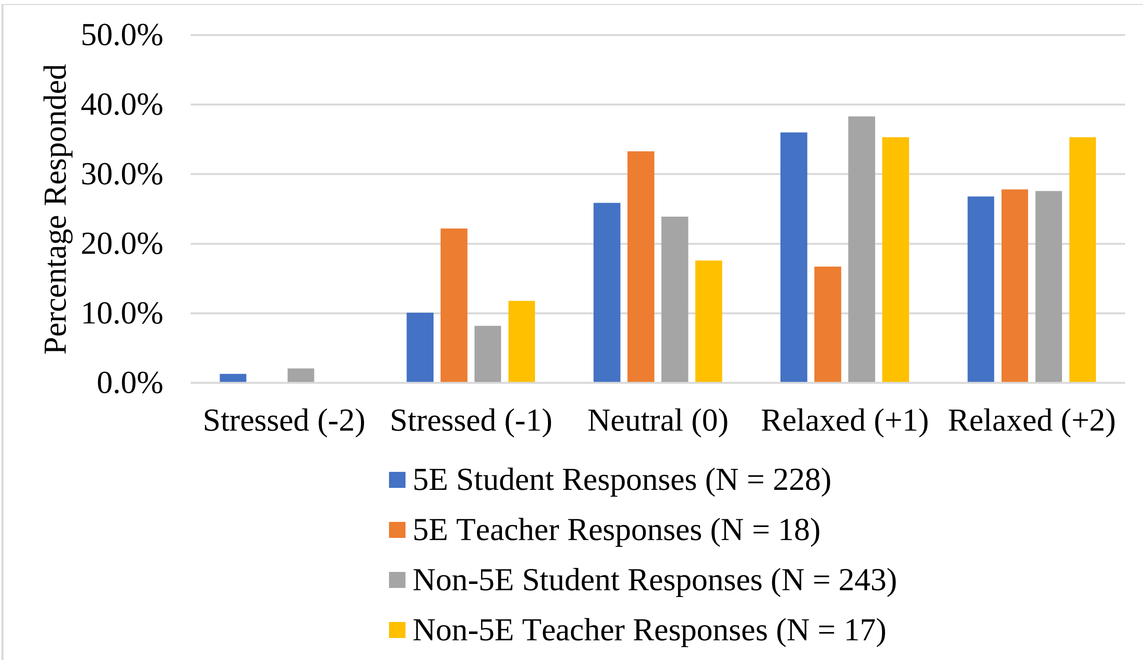

Figure 11. Impact of 5E and non-5E units on teacher's stressed versus relaxed level, (5E Student *N* = 228, Non-5E Student *N* = 243, 5E Teacher *N* = 18, Non-5E Teacher *N* = 17).

A close analysis of teacher and student responses (Figure 12) regarding how overwhelmed or encouraged I was indicates that I was more likely to rate myself as overwhelmed (-2 or -1) than my students were for both unit types. Student and teacher scores indicating I was encouraged (+1 and +2) were very similar for non-5E units but the same cannot be said for the 5E units. Following the 5E units, three students wrote specific comments about me being overwhelmed though they did not score me particularly low (0, 0, and -1). All three comments related to the Biomimicry Invention Project. One student wrote that "Mrs. Dalbey was sometimes overwhelmed because everybody needed help and she was very busy." My own notes referenced something similar on our first day working on the project, "the laptop cart I checked out is in horrible shape and students had a lot of problems getting logged on between missing keys, forgotten passwords, etc." Thankfully many of the technology glitches were resolved the following day. The other two students mentioned that "she was overwhelmed because most people weren't doing the work in the time they were given" and that "some people make it hard for you." The first remark is from a student in my largest, highest energy class and the latter from a class with a student with oppositional defiant order whom I suspect the student is referring to. The Student Feedback Forms from the two non-5E units included only one comment referencing me being overwhelmed when a student said, "I answered the questions above in this way because kids are really hard to take care of, especially because you're the only one taking care of them." This was an interesting observation given there is a support staff member in the room that class period. She is extremely reluctant to engage with him though as she is quite shy. Student comments indicate I was more prone to be overwhelmed during 5E units than non-5E units but I think the issue is better attributed to the challenges of incorporating poorly cared for technology in the room than instruction with the 5E Learning Cycle.

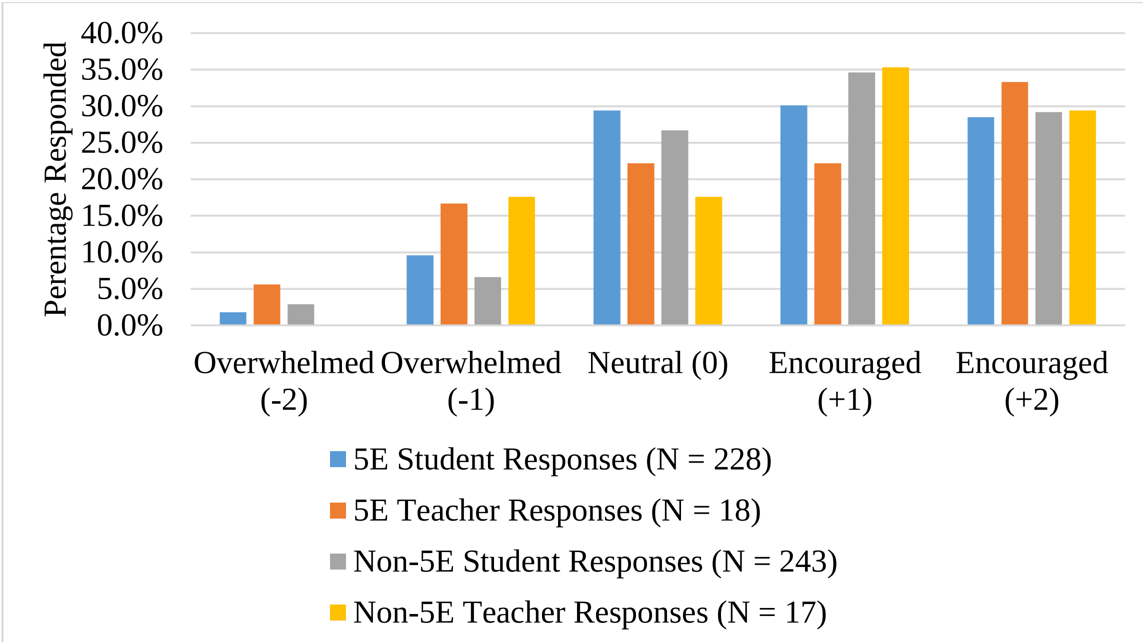

Figure 12. Impact of 5E and non-5E units on teacher's overwhelmed versus encouraged level, (5E Student *N* = 228, Non-5E Student *N* = 243, 5E Teacher *N* = 18, Non-5E Teacher *N* = 17).

When evaluating how sluggish versus energized I was (Figure 13), I was slightly more likely than students to rate myself as sluggish (-2 or -1). I think this was more influenced by the time of day I completed the reflection forms than the instructional methods; I completed the form right after school after just having taught four consecutive classes after lunch, two of which are very high energy and one of which is high needs. In reviewing students' comments about my energy levels, the only comments specific to me being sluggish were during the non-5E Levels of Organization unit when I was battling a head cold. Five students score me either 0, -1, or -2 and mentioned me being tired, three of whom specifically mentioned the cold. The only time I scored myself mildly (-1) or strongly (-2) sluggish, I referenced a period of sleeplessness during the night before or my cold. Like the stressed versus relaxed analysis discussed earlier in this section, outside factors seem to have a greater influence on my sluggish versus overwhelmed levels than instructional methods.

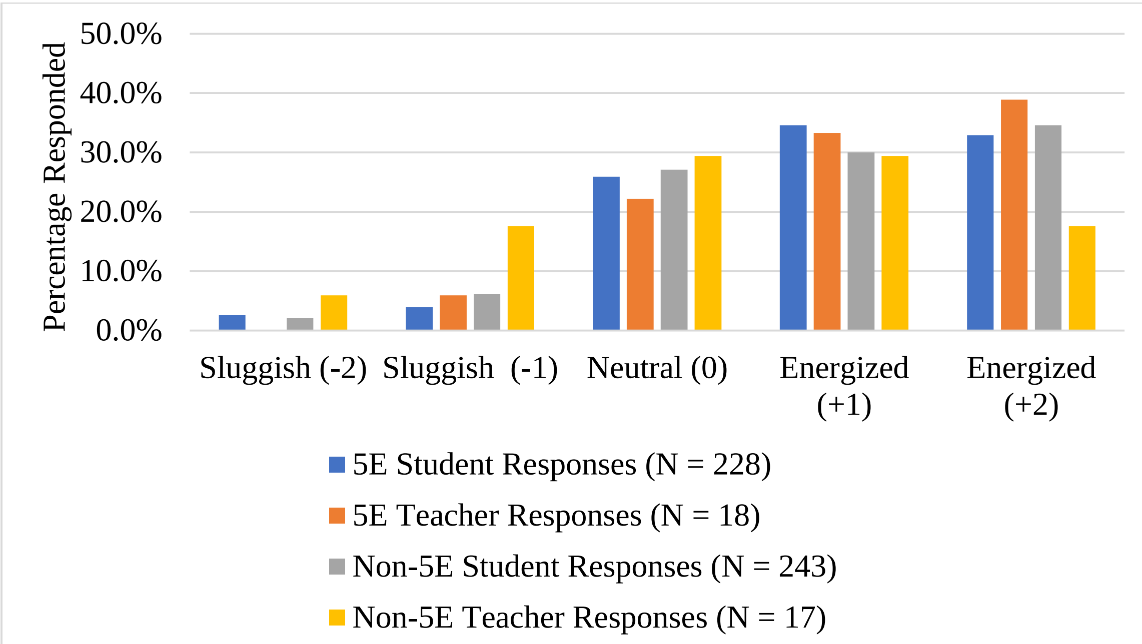

Figure 13. Impact of 5E and non-5E units on teacher's sluggish versus energized level, (5E Student *N* = 228, Non-5E Student *N* = 243, 5E Teacher *N* = 18, Non-5E Teacher *N* = 17).

When reviewing the data for how bored versus curious (Figure 14) I was, the only units for which I ever rated myself bored (-1) were non-5E units. During the non-5E Change Over Time unit I commented that "The vocabulary matrix was boring for me because the students did not require much interaction with me while they worked on it." Another day, during the non-5E Levels of Organization unit, I noted that "doing the notes with six classes is boring, though kids did ask some good questions and it allowed me to do some grading and organizing while students completed the notes." Throughout the Student Reflection Forms, there were only four students who made a substantial statement regarding my level of boredom versus curiousness. Only one of those comments came from a 5E unit and the student scored me as neutral (0) and said that “she had already done the lab with 5 other classes” as she is in my last class of the day. When responding to non-5E units, other students stated that, “Mrs. Dalbey was curious on how students were doing,” “she was curious about what we had to say,” and “she is full of curiosity.” It was interesting to note that I was more likely to rate myself very curious (+2) than students were for both unit types. I suspect there is a discrepancy between the two because I do not verbalize everything I am curious about with students.

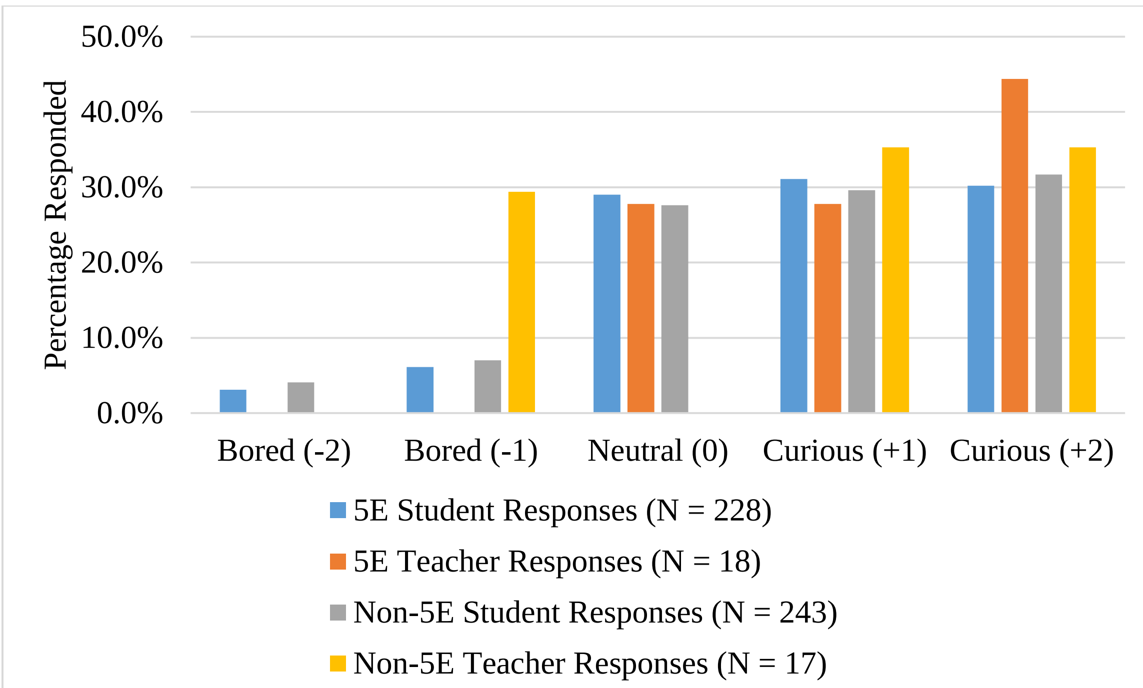

Figure 14. Impact of 5E and non-5E units on teacher's bored versus curious level, (5E Student *N* = 228, Non-5E Student *N* = 243, 5E Teacher *N* = 18, Non-5E Teacher *N* = 17).

The strongest pattern that emerged from analysis of the student responses to the four Student Feedback Forms (Figure 15) was that the students were more likely to rate me very patient (+2) than they were any other item on the form, regardless of the unit. For 5E units, they rated me as such 42.8% of the time and for non-5E units, 41.2% of the time. Though initially I took this as a compliment, it also made me question whether this perceived patience on students’ part equates to a lack of urgency in tackling tough challenges and completing work for some of my most reluctant students. Whether I was impatient or patient generated more comments from students on the Student Feedback Forms than any other attribute assessed so turned to them to try to determine whether my patience was a benefit to students or a crutch. Thankfully students from all 5 grade bands (A, B, C, D, and F) for their third quarter grades commented on this attribute so I had plenty of comments to review. From those students who indicated I was patient with a +1 or +2, an A student stated that "Mrs. Dalbey takes time to make sure her students understand and remember" for a 5E unit. A student with a C observed that "she's never…impatient" and a student with a D noted that "some students were kinda irritating but she was calm and patient." A student with an F for third quarter due to numerous absences and missing assignments stated that "I thought you were kind enough to give us extra time to work on assignments" to explain her +1 rating. I was especially interested in explanations from students who scored me as impatient for a unit (-2 or -1) and again found that students from all grade bands had something to say. During the 5E Biomimicry unit, an A student stated that "Mrs. Dalbey was a little more impatient and rushed us more than usual" while a C student on a non-5E unit stated that "this [unit] was really rushed" to explain her -2 rating. A student who earned a D third quarter rationalized his -2 rating with "she was eager to get done with the project." It is unclear whether he was referring to the classroom research project or the non-5E unit he was reflecting on. The response from him did not surprise me as it took substantial prodding to get him to complete the performance assessment associated with the unit. In general, I felt that students' comments indicated that my patience was beneficial for them and did not get a sense that I was overly patient to the point that it was allowing students to opt out of learning and work completion.

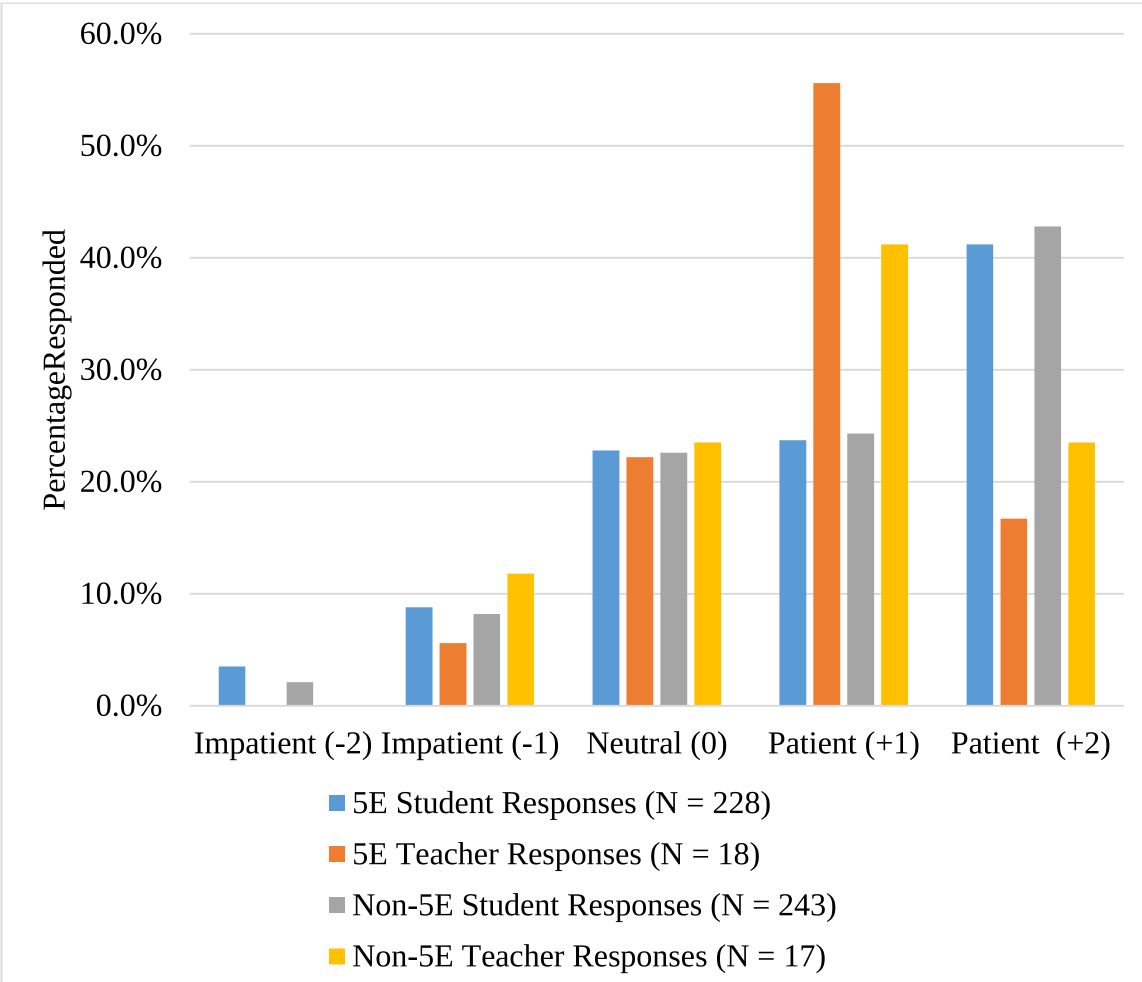

Figure 15. Impact of 5E and non-5E units on teacher's impatient versus patient level, (5E Student *N* = 228, Non-5E Student *N* = 243, 5E Teacher *N* = 18, Non-5E Teacher *N* = 17).

INTERPRETATION AND CONCLUSION

The focus of this action research project was to assess the impact of the 5E Learning Cycle on students' learning and retention of science content and how the teaching method impacted me as a teacher. In reviewing the data collection tools used to assess how the 5E Learning Cycle impacted student learning, a definitive statement for or against the 5E Learning Cycle cannot be made. Normalized gain scores for pre- and post-unit tests suggest that students may better learn science content with non-5E units. A Wilcoxon signed rank test comparing the average normalized gain scores for the two units indicated there was a statistically significant difference in the two samples at $\alpha = 0.05$. Figure 3 indicates that students were more likely to have a larger normalized gain score on non-5E units than 5E units. For the 5E units, students receiving special education services were disproportionately represented in the group of students with normalized gain scores one or more standard deviations below the normalized gain score averages (Table 7). For the non-5E units, all students with normalized gain scores one or more standard deviations above the average were general education students (Table 8). These pre- and post-unit test results suggest that non-5E may be the best teaching strategy to meet the needs of most of my students.

While the results of the pre- and post-unit tests suggested that non-5E lessons may result in the most learning for students, those results are contradicted by the results of students' performance assessment scores. A paired t-test of students' average performance assessment scores for the two unit types revealed a statistically significant difference at $\alpha = 0.05$ in scores between the 5E and non-5E units. This analysis, along with Figure 5, suggests that students may better demonstrate learning on performance assessment tasks embedded within 5E units than for those associated with non-5E units.

Analysis of concept map scores did not yield any statistical difference between the two unit types, further eroding the ability to make a strong statement for or against the 5E Learning Cycle (Figure 6). Concept map results did suggest however that students identified as gifted learners may especially benefit from the 5E Learning Cycle as they scored one or more standard deviations above the average difference between pre- and post-unit assessments at a much higher percentage than their representation within the general seventh-grade population (Table 14).

In assessing the 5E Learning Cycles impact on students' retention of science concepts, post-unit and delayed-post unit tests, Essential Vocabulary Progress Checks, and one-on-one student interviews were utilized. When comparing post-unit to delayed-post unit scores, student retention of content for both 5E and non-5E units appear high (Figure 7). Only one unit, the non-5E Change Over Time, had a statistically significant difference between the post-unit and delayed-post unit scores (Table 15) which was attributed to factors beyond the method of instruction. The two-part Essential Vocabulary Progress Check indicated that students recall essential vocabulary terms better with 5E units than non-5E units (Figure 8). This held true for both questions requiring students to correctly match terms with their definitions and on multiple-choice questions assessing their comprehension of the terms. The number of words assessed, especially for the 5E Learning Cycle units, was small though so I am hesitant to make a strong statement for the 5E Learning Cycle on key term retention based on just this four-unit study. One-on-one interviews with a very small sample of randomly selected students suggested that students' longer-term recall of content and ideas between 5E and non-5E units was similar (Figure 9).

When evaluating the impact of the 5E Learning Cycle on me as a teacher, I found that use of the 5E Learning Cycle Lesson Plan Template helped to guide my development of inquiry-based instruction that followed the five phases of the learning cycle. Use of the rubric to evaluate the two 5E units utilized indicates that I can generate 5E Learning Cycle lessons when adequate time is available for curriculum development. A comparison of my Self-Reflection Forms and Student Feedback Forms suggests that there is no clear distinction on me as a teacher between the 5E Learning Cycle units and the non-treatment units on my stress, encouragement, energy and patience levels (Figures 11, 12, 13, and 15). Daily qualitative journaling during the classroom research project revealed that factors outside my classroom influence had a greater impact on those levels than the type of instruction being implemented. Next year will bring many changes in my teaching assignment, including block scheduling, shared teaching of one class period, and teaching physical science for the first time. It will be a year filled with many opportunities for growth but also challenges. To try to minimize the negative impacts of a year with so many changes, I plan to make a conscious effort regarding self-care (adequate sleep, exercise, nutrition, surrounding myself with positive colleagues and situations, etc.). As teachers, I think we need to do a better job of giving ourselves and our colleagues permission and reminders to care for ourselves so we can best serve our students. Though many of things that impacted me as a teacher were not tied to the type of instruction, one notable exception was on my bored versus curiosity scores (Figure 14). I was more likely to rate myself “curious” during the 5E units than the non-5E units. This was due to the greater variety of questions and ideas encountered as students worked on more divergent ideas and projects and I coached them through the 5E process.

The results of this classroom research project are largely inconclusive about the use of the 5E Learning Cycle as some data collection tools generated evidence for or against the 5E Learning Cycle while others indicated no significant difference between student learning and retention between the two instructional methods. The 5E Learning Cycle units allowed for student learning that was in alignment with the constructivist theory. Students worked collaboratively with their peers and myself to build understanding as prescribed by Dewey (Llewellyn, 2014). In line with Piaget's theories, the 5E performance assessments actively engaged students and provided them opportunities to experience phenomenon prior to introduction of vocabulary during the Explain phase of the 5E Learning Cycle (Llewellyn, 2014). Though some students were able to complete the performance assessments independently, many required interaction with their peers and myself which provided language opportunities that shape mental development as Vygotsky's work suggests (Llewellyn, 2014).

At least two possible explanations may account for the lack of clear results for or against the 5E Learning Cycle in this classroom research project. One possible explanation is that some of the non-5E unit activities embraced components of the constructivist theory which skewed results. Had I used a non-treatment that was only vocabulary and worksheets, I might have gotten different results. Another possible explanation is that I am not yet completely adept at designing inquiry-based lessons and/or guiding all students through the inquiry-process toward increased scientific understanding and that was reflected by conflicting results from the many data collection tools.

Moving forward, my instruction will be shaped in numerous ways by my completion of this classroom research project. The process reaffirmed the benefits of using a variety of pre- and post-unit assessments throughout the year so both myself and students can see evidence of their learning and adjust instruction as needed. Though the concept mapping required significant upfront training of students, I plan to use the technique moving forward as I feel it forced students to interact with the content at a higher cognitive level than other assessments tools. Concept maps also provided a window into student understanding that other assessment tools were lacking. I do not plan to use it with every unit or consecutive units but multiple times throughout the year as I believe doing so would give students an additional way to show their understanding and study without them undergoing "concept-map burnout" as some students did. I will continue to use and design 5E Learning Cycle units periodically throughout the upcoming years. The addition of physical science to my teaching load next year adds a multitude of great opportunities to start lessons with discrepant events in the Engage phase which I find harder to do with life science. As I work with my colleague to plan our seventh and eighth grade science lessons next year, I will share with him the value I found in using pre- and post-assessments more regularly, the benefits of teaching students to do concept mapping, and work with him to include 5E Learning Cycle units throughout the year. This classroom research project was ripe with learning opportunities for myself and my students and I will continue to reflect on and apply lessons learned through the project throughout my teaching career.

VALUE

Looking both back and forward there are numerous benefits to completing this classroom research project. In looking back, this year's students saw me demonstrate a lifelong commitment to learning as they joined me for this classroom research project. They learned to interpret box and whisker plots to look for their own and their peers' growth. They learned how to create concept maps as a tool for both studying and showing their understanding. I hope they learned that we all grow at different rates and amounts but that personal growth in general is what really matters. For me, this project provided an opportunity to relearn a lot of statistical principals and techniques, helped me to develop a habit of written reflection as opposed to more informal reflections, and refreshed my desire to dig deeper with inquiry-based teaching methods.

Looking forward, I feel better equipped to embark on data collection and analysis with my middle school science professional learning community, though it certainly will not be on as grand a scale as this project. The timing is especially helpful as next year I will have others' data to compare to since my colleague and I are both teaching seventh and eighth grade science. I look forward to working and learning with him how we can best help our students learn. The Engage phase of the 5E Learning Cycle inspired me to seek out and incorporate a lot of discrepant events to use next year in my physical science classes.

The stresses outside my classroom control during this classroom research project and their impact on my daily reflections reinforced the need for self-care for myself and my peers. Next year our building will experience more transitions than any since I have been there and we all need to remember that we cannot best serve our students without also caring for ourselves and one another.

Though this classroom research project required a lot of time and sacrifices along the way, I feel the tradeoffs are well worth the short-term costs and am so thankful for those who encouraged me to pursue this journey.

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APPENDICES

APPENDIX A

ASSORTMENT OF TESTS

Changes Over Time Unit Pre-test Name ________________ Period ___ Score ___/10

Matching: *Match each term with the correct description below.*

adaptation
artificial selection
camouflage
evolution
natural selection
species
variation

1. ____________________ change in the features of a type of organism over time
2. ____________________ when an organism blends into its environment
3. ____________________ survival of the fittest
4. ____________________ a trait that makes an individual different from other members of its species
5. ____________________ a variation that increases an individual's chance to survive and reproduce
6. ____________________ the breeding of certain plants and animals by humans to get desired traits
7. ____________________ a group of organisms that look alike and can reproduce among themselves
8. "Evolution continues to occur in organisms today."
   True or False? _______ Explain your answer: ________________________________
   ____
   ____
9. "A change in the environment is required for a new species to evolve."
   True or False? _______ Explain your answer: ________________________________
   ____
   ____
10. *Choose ONE of these questions to answer. The second can be answered for extra credit without penalty.*
   Why are mutations crucial for natural selection?
   ____
   ____
   ____
   ____

   Explain why variation, selection, and time is the "recipe" for evolution.
   ____
   ____

____

____

Adaptations & Biomimicry Unit Pre-test Name ____________ Period __ Score __/10

Matching: *Match each term with the correct description below.*

adaptation	function
biodiversity	structure
biomimicry	sustainable
efficient	

1. ____________________ the variety of life in the world or in a habitat or ecosystem
2. ____________________ harvesting or using a resource in a way that it is not depleted or permanently damaged
3. ____________________ making or using something without waste of resources or energy
4. ____________________ the form of an object (its shape)
5. ____________________ a variation that increases an individual's chance to survive and reproduce
6. ____________________ using nature to inspire human designs
7. ____________________ an objects function (its job)
8. *Identify the following below:*

biomimetic solution ***human need*** ***nature's example***

Wind turbine developers want to generate as much power as possible per wind turbine.	
Humpback whales have tubercles (bumps) on the leading edge of their fins that decrease drag in the water and allow them to maneuver better in the water.	
WhalePower wind turbine blades have bumps on their leading edge that decrease the drag on the blades and increase the amount of power generated by 20%.	

9. "Nature can be used to solve human design problems."
True or False? _______ Explain your answer: ______________________________
____
____

10. "A sustainable world already exists."
True or False? _______ Explain your answer: ______________________________
____
____

Levels of Organization Pre-test Name ________________ Period ___ Score ___/10

Place these five levels of organization in order from smallest to largest.

cell organ organism organ system tissue

SMALLEST___________ ___________ ___________ ___________ ___________LARGEST

Matching: *Match each term with the correct description below.*

circulatory system
digestive system
excretory system
nervous system
respiratory system

6. ____________________ organ system that takes in food, breaks food down, and eliminates the solid waste
7. ____________________ organ system that collects waste from the bloodstream and eliminates the waste as urine
8. ____________________ organ system that takes in oxygen and eliminates carbon dioxide through breathing
9. ____________________ organ system that moves materials through the body using the heart, blood vessels, and blood
10. ____________________ organ system that sends and receives information throughout the body

Nervous System Unit Pre-test Name ________________ Period ___ Score ___/10

Matching: *Match each term with the correct description below.*

brain	spinal cord
central nervous system	neuron
interneuron	peripheral nervous system
motor neuron	sensory neuron

1. ____________________________ part of the nervous system made of the brain and spinal cord

2. ____________________________ part of the nervous system made of nerves stretching away from the spinal cord

3. ____________________________ large organ in your skull responsible for controlling most of the body's functions

4. ____________________________ long organ that runs down the inside of the spine

5. ____________________________ another name for a nerve cell

6. ____________________________ nerve cell that connects nerve cells to one another

7. ____________________________ nerve cell that picks up messages of pain, heat, cold, pressure, etc. from receptors throughout the body

8. ____________________________ nerve cell that tells muscles to move

9. ____ What is the main job of the nervous system?
   A. to control the body using hormones
   B. to send and receive messages between the brain and body
   C. to collect waste from the bloodstream
   D. to provide a layer of protection between the outside world and inside body

10. Why is it that spinal cord injuries closest to the skull are most damaging?
    ____
    ____
    ____

APPENDIX B

PERFORMANCE ASSESSMENT RUBRICS

Mouse Lab Performance Assessment Name(s) ______________ Period __ Score __/16

Points Possible	**1**	**2**	**3**	**4**
Death rate calculations (#1, #2, #5, and #6)	Did not correctly calculate the death rate for any data set OR did not attempt to calculate any death rates.	Accurately calculated the death rate for 1 data set.	Accurately calculated the death rate for 2-3 data sets.	Accurately calculated the death rate for all four data sets.
White sands conclusion (#4)	Explanation for how the mouse population might change over time is unreasonable OR no explanation is offered.	Explanation for how the mouse population might change over time is reasonable but includes major misconceptions.	Explanation for how the mouse population might change over time is reasonable but includes minor misconceptions.	Explanation for how the mouse population might change over time is reasonable and includes no misconceptions.
Forest floor conclusions (#9)	Explanation for how the mouse population might change over time is unreasonable OR no explanation is offered.	Explanation for how the mouse population might change over time is reasonable but includes major misconceptions.	Explanation for how the mouse population might change over time is reasonable but includes minor misconceptions.	Explanation for how the mouse population might change over time is reasonable and includes no misconceptions.
Model critique (#10 and #11)	Lacks any explanations of how the model is accurate or inaccurate.	Lacks either an explanation of how the model is accurate or inaccurate for modeling natural selection.	Identifies 1 way in which the model is both accurate and inaccurate in modeling natural selection.	Identifies 2 or more ways in which the model is both accurate and inaccurate in modeling natural selection.

Biomimicry Invention Project Performance Assessment Rubric

Name(s) ___________________________________ Period __________ Score ____ /25

Required Items	**Did Not Attempt (0)**	**Needs Improvement (3)**	**Good (4)**	**Great (5)**
Problem Summary (Day 1 Tasks)	No attempt was made.	Summary does not fully explain the problem.	Summary explains the problem, but does not include the question in biological terms.	Complete summary and problem are explained in detail and in biological terms.
Research (Day 1 Tasks)	No attempt was made.	Keywords/search terms are not included OR 2 sources are not credited.	Keywords/search term are included and 2 sources are credited.	Keywords/search terms are included and more than 3 sources are credited.
Inspired by Nature (Day 2 Tasks)	No attempt was made.	Nature is not mentioned in the design.	Nature is referenced, but the connection from nature to the design is not fully explained.	Describes how the design was inspired by nature and how nature was incorporated into the design.
Display Product (Day 3 Task)	No attempt was made.	Missing two of the following: labels, measurements, or materials used. Might be messy and colorless.	Missing one of the following: labels, measurements, or materials used. Product is messy or lacking color.	All of the following are included: labels, measurements, or materials used. Product is neat and colorful.
Gallery Walk	No attempt was made.	Display requires a verbal explanation/live presenter to comprehend.	The problem, connection to nature, and solution are mostly there but display is difficult to interpret.	Display conveys the problem, connection, and solution. It is standalone and can be easily interpreted by the viewer.

Extra Credit Opportunity (individual students only): Individual students can choose to build a 3D prototype (model) of their design. The prototype must be submitted at the same time as the group project (Gallery Walk day). Up to 5 points available.

Human Body Levels of Organization Performance Assessment

Name ________________________________ Period _______________ Score _____ / 16

	4	**3**	**2**	**0**
Debate: made meaningful contributions to class debate	• Made 3+ meaningful contributions to class debate, at least one of which referenced specific evidence.	• Made 2 meaningful contributions to class debate, at least one of which referenced specific evidence.	• Made 1 meaningful contribution to class debate. • May or may not have referenced specific evidence.	Did not participate in debate.
Claim: a conclusion that answers the original question	• Scientifically accurate • Completely answers the question. • Addresses inaccurate statements from assessment probe.	• Scientifically accurate • Completely answers the question. • Does not address inaccurate statements from assessment probe.	• Scientifically inaccurate • May or may not completely answer the question. • Does not address inaccurate statements from probe.	No claim.
Evidence: scientific data or observations that supports the claim	• Evidence presented are appropriate to the claim. • Explains evidence why alternate claims do not work.	• Evidence presented are appropriate to the claim. • Does not explain evidence why alternate claims do not work.	• Evidence presented is not logically linked to the claim.	No evidence provided.
Reasoning: a justification that links the claim and evidence	• Reasoning clearly links evidence to claim. • Reasoning demonstrates depth of understanding about the claim.	• Reasoning clearly links evidence to claim. • Reasoning does not demonstrate depth of understanding about claim.	• Reasoning is insufficient and/or doesn't link clearly the claim and evidence. • Limited understanding about the claim.	Does not provide reasoning.

Nervous System Lab Performance Assessment

Name(s) ____ Period ___ Score ___/16

Points Possible	**1**	**2**	**3**	**4**
Data Collection and Display (#1—on front)	Did not record response times for all group members.	Recorded response times for all group members but did not graph results.	Recorded and graphed the response times for all group members.	Recorded and graphed the response times for all group members. Graph includes increments and units on vertical axis.
Data Analysis (#2 and #3—on front)	Accurately calculated 0-2 averages.	Accurately calculated 3-4 averages.	Accurately calculated 5-6 averages.	Accurately calculated all 7 averages.
Data Display (#4 on front)	Graph may be tidy, but is lacking all of the following: • title • clearly numbered intervals • labels for both the x- and y-axes.	Graph may be tidy, but is lacking two of the following: • title • clearly numbered intervals • labels for both the x- and y-axes.	Graph is either not tidy OR is lacking one of the following: • title • clearly numbered intervals • labels for both the x- and y-axes.	Graph is tidy and includes all of the following: • title • clearly numbered intervals • and labels for both the x- and y-axes
Data Analysis and Conclusion (back)	Reasonably answered 0-3 questions on the back of the worksheet.	Reasonably answered 4-5 questions on the back of the worksheet.	Reasonably answered 6-7 questions on the back of the worksheet.	Reasonably answered 8-9 questions on the back of the worksheet.

APPENDIX C

CONCEPT MAP RUBRICS

Name: ________________________________ Date: ______________ Period: ____

Standard(s): ____
____
____
____

Concept Map Directions and Self-Evaluation

Directions: Make a concept map on the back of this paper using the main idea and words from the Word Bank. You can add additional words to show a deeper understanding. Then score yourself for each of the five components below.

Main Idea: _______________________
Word Bank
(key vocabulary words for the unit will be provided here)

Use this scale to complete the self- evaluation below:

0 = not at all 1 = partial 2 = complete

As you look at your concept map, ask yourself how well did I…

1. place the main idea at the top of the page? ___ (2 points)
2. organize the words or concepts from most general to most specific? ___ (2 points)
3. use linking words (verbs, prepositions, or short phrases) to show relationships from one idea to another? ___ (2 points)
4. use cross links to make connections between words in different areas of the map? ___ (2 points)
5. use vocabulary words NOT provided in the word bank? ___ (2 points)

Total Points: ___ / 10 points

Modified from:

Magonigle, Margaret K. (2011). *The Effects of Using an Inquiry-approach through the 5E Lesson Format on Middle School Earth and Space Science Students.* (Professional paper submitted for Master of Science in Science Education in Bozeman, MT).

Name: ________________________________ Date: ______________ Period: ____

Concept Map Teacher Evaluation (Pre-Unit)

Concept Map Component	**Possible Points**	**Points Earned**	**Notes**
Main topic at top of concept map	1		
Hierarchy levels	5 each		
Cross links	10 each		
Vocabulary beyond given terms	1 each		
Examples	1 each		
Meaningful **linking words** (verbs, prepositions, short phrases)	2 each		
Total:			

Concept Map Teacher Evaluation (Post-Unit)

Concept Map Component	**Possible Points**	**Points Earned**	**Notes**
Main topic at top of concept map	1		
Hierarchy levels	5 each		
Cross links	10 each		
Vocabulary beyond given terms	1 each		
Examples	1 each		
Meaningful **linking words** (verbs, prepositions, short phrases)	2 each		
	Total:		

Score difference between pre-unit and post unit concept maps: ___________

Modified from:

Cook, Lacy C. (2012). *Making Connections: Teaching and Using Concept Maps in a Fourth Grade Mathematics Class.* (Professional paper submitted for Master for Science in Science Education in Bozeman, MT).

Novak, J.D. & Gawin, D. B. (1984). *Learning How to Learn*. New York, NY: Cambridge University Press.

APPENDIX D

ESSENTIAL VOCABULARY PROGRESS CHECK

Essential Vocabulary Progress Check Name _________________ Period ___ Score ____/33

Topic: Structure and Function of Cells

1		a rigid structure found outside plant cells and some other single-celled organisms
2		basic unit of life
3		cell organelle that contains DNA and controls most cell functions
4		cell organelle where glucose is broken down to release energy
5		green organelle found in plants that is the site for photosynthesis
6		process by which producers and consumers release energy stored in sugar molecules
7		process in which plants and some other organisms use water, carbon dioxide, and sunlight to make food (glucose)
8		the organelle that controls what enters and leaves the cell
9		what something does (its job)
10		what something looks like (its form)

Topic: Genetics

11		a change in a gene or chromosome; can be helpful, harmful, or neutral
12		a process by which organisms best suited to their environment are more likely to survive and reproduce
13		a trait that makes a living thing more likely to survive
14		the breeding of certain plants or animals by humans to get desired traits
15		type of reproduction (fission, budding, regeneration) that forms a new organism that is identical to its parent
16		type of reproduction where two cells join to form a new organism, offspring is not identical to either parent cell

Topic: Human Body

17		a group of different tissues that work together to perform a function
18		a group of organs that work together to perform a major body function
19		a group of similar cells that work together to perform a function
20		organ system that collects waste from the bloodstream and eliminates the waste as urine
21		organ system that moves materials through the body using the heart, blood vessels, and blood
22		organ system that moves the body using muscles
23		organ system that sends and receives information throughout the body
24		organ system that takes in food, breaks food down, and eliminates solid waste
25		organ system that takes in oxygen and eliminates carbon dioxide through breathing

Topic: Environmental Science

26		a community of interacting organisms and their physical environment
27		a diagram that shows the flow of energy from producers to consumers in a food web
28		a living thing (plant, animal, protist, fungus, bacteria)
29		a relationship between two living things in which both benefit
30		all members of one species in a specific area
31		the variety of life in an area
32		when an animal feeds on another animal for food
33		when living things compete for a limited resource

Regular Education Word Bank		**Special Education Word Bank**
		#1-11
adaptation		cell
artificial selection		cell membrane
asexual reproduction		cell wall
biodiversity		chloroplast
cell		function
cell membrane		mitochondria
cell wall		mutation
chloroplast		nucleus
circulatory system		photosynthesis
competition		respiration
digestive system		structure
ecosystem		**#12-22**
energy pyramid		adaptation
excretory system		artificial selection
function		asexual reproduction
mitochondria		circulatory system
muscular system		excretory system
mutation		muscular system
mutualism		natural selection
natural selection		organ
nervous system		organ system
nucleus		sexual reproduction
organ		tissue
organ system		**#23-33**
organism		biodiversity
photosynthesis		competition
population		digestive system
predation		ecosystem
respiration		energy pyramid
respiratory system		mutualism
sexual reproduction		nervous system
structure		organism
tissue		population
		predation
		respiratory system

Essential Vocabulary Comprehension Progress Check—General Education Version
Please record answers on provided answer sheet.

1. ONLY living things are made of
   A. atoms.
   B. cells.
   C. molecules.
   D. protons, neutrons, and electrons.

2. A hummingbird has a long, thin narrow beak. This describes the beak's
   A. function.
   B. job.
   C. structure.
   D. operation.

3. A giraffe's neck allows it to reach high leaves. This describes the neck's
   A. form.
   B. function.
   C. shape.
   D. structure.

4. A red blood cell in fresh water swells as it absorbs water. The water would have to pass through what structure to enter the cell?
   A. cell membrane
   B. cell wall
   C. cytoplasm
   D. nucleus

5. If something weakens the cell walls of a plant's cells, what impact would it have on the plant?
   A. The plant would wilt.
   B. Photosynthesis would stop.
   C. Gas exchange between the plant and surrounding air would stop.
   D. The plant would lose its green color.

6. Plant roots are not green. With no access to sunlight, they can't do photosynthesis. What plant cell part do roots lack?
   A. cell membrane
   B. cell wall
   C. chloroplast
   D. cytoplasm

7. The dark meat muscles of a bird require a lot of energy for flight. Which cell part is abundant in the dark meat muscles?
   A. cell membrane
   B. chloroplast
   C. mitochondria
   D. nucleus

8. Mature red blood cells lack an important cell part. As result, they can't repair themselves if damaged because they don't have the directions to do so. What cell part are they lacking?
   A. cell membrane
   B. cytoplasm
   C. mitochondria
   D. nucleus

9. Thanks to submarines, we've discovered ecosystems on the ocean floor where no sunlight penetrates. What cell process do these communities NOT rely on?
   A. meiosis
   B. mitosis
   C. photosynthesis
   D. respiration

10. Without sugar and/or oxygen, most cells start to die. What cell process stops without sugar or oxygen?
    A. meiosis
    B. mitosis
    C. photosynthesis
    D. respiration

11. A predator has sharp teeth which help it to kill and eat prey. This is an example of what?
    A. an adaptation
    B. an organ
    C. competition
    D. respiration

12. All physical differences in individual members of a species came about because of ______________.
    A. artificial selection
    B. mutations
    C. respiration
    D. asexual reproduction

13. This type of reproduction generally produces generation after generation that are identical.
    A. asexual reproduction
    B. sexual reproduction
    C. cross-pollination
    D. self-pollination

14. Because offspring receive genetic information from two different parents, each generation is generally different than the parents' generation.
    A. asexual reproduction
    B. sexual reproduction
    C. budding
    D. regeneration

15. Today's domestic dogs are often very different from their wolf ancestors. This is due to what <u>human</u> behavior?
    A. artificial selection
    B. natural selection
    C. respiration
    D. predation

16. Over time, what <u>natural</u> process can lead to changes in a species?
    A. artificial selection
    B. natural selection
    C. photosynthesis
    D. respiration

17. The femur (bone in your leg) is made of 3 tissues: connective, nerve, and epithelial. Which level of organization is your femur?
    A. cell
    B. organ
    C. organ system
    D. tissue

18. The mouth, esophagus, stomach, and intestines work together to break down food. This is an example of what level of organization?
    A. cell
    B. organ
    C. organ system
    D. tissue

19. You look at a sample taken from an animal's leg. You see many cells that all have similar appearances. What level of organization are you examining?
    A. molecule
    B. organ
    C. organ system
    D. tissue

20. When you exercise hard, your muscles need more energy and oxygen. What organ system would help provide additional energy and oxygen for your muscles?
    A. circulatory system
    B. digestive system
    C. muscular system
    D. nervous system

21. If this system stops working, waste would build up in your bloodstream and poison you. What organ system is this?
    A. circulatory system
    B. digestive system
    C. excretory system
    D. muscular system

22. What would eventually happen to a person whose digestive system stopped working properly?
    A. No messages would travel between the body and brain.
    B. Their cells would run out of energy and needed materials to live.
    C. They would run out of oxygen and suffocate.
    D. Waste would build up in their bloodstream and poison them.

23. What organ system is very different in humans who breath air and fish who absorb dissolved oxygen from the water?
    A. digestive system
    B. excretory system
    C. nervous system
    D. respiratory system

24. What organ system is made of organs such as your biceps, triceps, quadriceps, and hamstrings that are attached to your skeleton and move your body?
    A. circulatory system
    B. digestive system
    C. excretory system
    D. muscular system

25. Injuries to the spine can block nerve messages between the body and brain. What organ system is most directly impacted by a spinal injury?
    A. digestive system
    B. excretory system
    C. nervous system
    D. respiratory system

26. Which of these four areas have the greatest biodiversity?
    A. Glacier National Park
    B. Mission Mountains
    C. Mrs. Dalbey's classroom
    D. The school garden

27. In the 1940s and 1950s, mountain goats were introduced to Yellowstone National Park. Since the 1980s, the number of bighorn sheep in the park have been lower. If mountain goats and bighorn sheep are sharing the same steep, rocky areas and food and that has caused the bighorn sheep numbers to go down, this is an example of ____________________.
    A. competition
    B. mutualism
    C. predation
    D. symbiosis

28. The aquarium in Mrs. Dalbey's room has guppies, an algae eater, waste from the fish, algae, bacteria, water, minerals, and dissolved oxygen. These things together make up the aquarium's __________________.
    A. community
    B. ecosystem
    C. organism
    D. population

29. In an energy pyramid, the most energy is available
    A. At the top where apex predators are located.
    B. In the middle where herbivores and some omnivores and carnivores are located.
    C. At the base where plants are located.
    D. Evenly spread throughout all layers.

30. If I give my dog food, water, and shelter and in return she gives me company and warns me of threats, this is an example of ___________________.
    A. competition
    B. mutualism
    C. parasitism
    D. predation

31. A mushroom, a pine tree, the bacteria that causes strep throat, and a human are each examples of a(n) __________.
    A. community
    B. ecosystem
    C. organism
    D. population

32. Together all the guppies in Mrs. Dalbey's fish tank are a(n) ________________________.
    A. community
    B. ecosystem
    C. organism
    D. population

33. When a grizzly bear eats an elk calf, this is an example of _____________________.
    A. competition
    B. mutualism
    C. parasitism
    D. predation

Essential Vocabulary Comprehension Progress Check—Special Education Version
Please record answers on provided answer sheet.

1. ONLY living things are made of
   A. atoms.
   B. cells.
   C. molecules.
   ~~D. protons, neutrons, and electrons.~~

2. A hummingbird has a long, thin narrow beak. This describes the beak's
   A. function.
   B. job.
   C. structure.
   ~~D. operation.~~

3. A giraffe's neck allows it to reach high leaves. This describes the neck's
   ~~A. form.~~
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   C. shape.
   D. structure.

4. A red blood cell in fresh water swells as it absorbs water. The water would have to pass through what structure to enter the cell?
   A. cell membrane
   B. cell wall
   C. cytoplasm
   ~~D. nucleus~~

5. If something weakens the cell walls of a plant's cells, what impact would it have on the plant?
   A. The plant would wilt.
   B. Photosynthesis would stop.
   ~~C. Gas exchange between the plant and surrounding air would stop.~~
   D. The plant would lose its green color.

6. Plant roots are not green. With no access to sunlight, they can't do photosynthesis. What plant cell part do roots lack?
   A. cell membrane
   B. cell wall
   C. chloroplast
   ~~D. cytoplasm~~

7. The dark meat muscles of a bird require a lot of energy for flight. Which cell part is abundant in the dark meat muscles?
   A. cell membrane
   ~~B. chloroplast~~
   C. mitochondria
   D. nucleus

8. Mature red blood cells lack an important cell part. As result, they can't repair themselves if damaged because they don't have the directions to do so. What cell part are they lacking?
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   B. cytoplasm
   ~~C. mitochondria~~
   D. nucleus

9. Thanks to submarines, we've discovered ecosystems on the ocean floor where no sunlight penetrates. What cell process do these communities NOT rely on?
   ~~A. meiosis~~
   B. mitosis
   C. photosynthesis
   D. respiration

10. Without sugar and/or oxygen, most cells start to die. What cell process stops without sugar or oxygen?
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    D. respiration

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    ~~B. an organ~~
    C. competition
    D. respiration

12. All physical differences in individual members of a species came about because of ______________.
    A. artificial selection
    B. mutations
    C. respiration
    ~~D. asexual reproduction~~

13. This type of reproduction generally produces generation after generation that are identical.
    A. asexual reproduction
    B. sexual reproduction
    C. cross-pollination
    ~~D. self-pollination~~

14. Because offspring receive genetic information from two different parents, each generation is generally different than the parents' generation.
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    B. sexual reproduction
    C. budding
    ~~D. regeneration~~

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    C. organ system
    ~~D. tissue~~

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    C. organ system
    D. tissue

19. You look at a sample taken from an animal's leg. You see many cells that all have similar appearances. What level of organization are you examining?
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    D. tissue

20. When you exercise hard, your muscles need more energy and oxygen. What organ system would help provide additional energy and oxygen for your muscles?
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    B. digestive system
    ~~C. muscular system~~
    D. nervous system

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    B. excretory system
    C. nervous system
    D. respiratory system

24. What organ system is made of organs such as your biceps, triceps, quadriceps, and hamstrings that are attached to your skeleton and move your body?
    ~~A. circulatory system~~
    B. digestive system
    C. excretory system
    D. muscular system

25. Injuries to the spine can block nerve messages between the body and brain. What organ system is most directly impacted by a spinal injury?
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    B. excretory system
    C. nervous system
    ~~D. respiratory system~~

26. Which of these four areas have the greatest biodiversity?
    A. Glacier National Park
    B. Mission Mountains
    C. Mrs. Dalbey's classroom
    ~~D. The school garden~~

27. In the 1940s and 1950s, <u>mountain goats</u> were introduced to Yellowstone National Park. Since the 1980s, the number of <u>bighorn sheep</u> in the park have been lower. <u>If</u> mountain goats and bighorn sheep are sharing the same steep, rocky areas and food and that has caused the bighorn sheep numbers to go down, this is an example of _______________________.
    A. competition
    B. mutualism
    C. predation
    ~~D. symbiosis~~

28. The aquarium in Mrs. Dalbey's room has guppies, an algae eater, waste from the fish, algae, bacteria, water, minerals, and dissolved oxygen. These things together make up the aquarium's ____________________.
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    B. ecosystem
    ~~C. organism~~
    D. population

29. In an energy pyramid, the most energy is available
    A. At the top where apex predators are located.
    ~~B. In the middle where herbivores and some omnivores and carnivores are located.~~
    C. At the base where plants are located.
    D. Evenly spread throughout all layers.

30. If I give my dog food, water, and shelter and in return she gives me company and warns me of threats, this is an example of _____________________.
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    B. mutualism
    C. parasitism
    D. predation

31. A mushroom, a pine tree, the bacteria that causes strep throat, and a human are each examples of a(n) ___________.
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    ~~B. ecosystem~~
    C. organism
    D. population

32. Together all the guppies in Mrs. Dalbey's fish tank are a(n) __________________________.
    A. community
    B. ecosystem
    ~~C. organism~~
    D. population

33. When a grizzly bear eats an elk calf, this is an example of _______________________.
    A. competition
    B. mutualism
    ~~C. parasitism~~
    D. predation

lame ________________ Period ___

Score ____/33

Essential Vocabulary Progress Check

Comprehension Answer Sheet

	A	B	C	D
1				
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APPENDIX E

STUDENT INTERVIEW QUESTIONS

Name ________________________ Period _____ Date ___________ Time __________

Genetics—Changes Over Time Student Interview Questions (non-5E)

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

1. ____ Please explain how mutations in one individual can lead to changes in a species.

2. ____ How are artificial selection and natural selection different from one another?

3. ____ How are artificial selection and the domestication of plants and animals related?

4. How did this unit help you better understand your world?

5. What activities/lessons do you remember best from our *Genetics—Changes Over Time* unit?

6. Is there anything else you would like me to know?

Interviewer Rating Scale		
Numerical Score	**Label**	**Description**
1	Below basic	Student demonstrated no understanding of concept or had major misconception(s).
2	Basic	Student demonstrated very limited understanding of the concept or had minor misconception(s).
3	Proficient	Student demonstrated understanding of concept.
4	Advanced	Student demonstrated understanding of concept and answered probing questions at a higher level.

Name ________________________ Period _____ Date ___________ Time __________

Adaptations and Biomimicry Student Interview Questions (5E)

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

1. ____ Please pick an animal and explain how some of its adaptations help it to survive.

2. ____ Please explain what biomimicry means.

3. ____ How can biomimicry be beneficial for humans? The environment?

4. How did this unit help you better understand your world?

5. What activities/lessons do you remember best from our *Adaptations and Biomimicry* unit?

6. Is there anything else you would like me to know?

Interviewer Rating Scale		
Numerical Score	**Label**	**Description**
1	Below basic	Student demonstrated no understanding of concept or had major misconception(s).
2	Basic	Student demonstrated very limited understanding of the concept or had minor misconception(s).
3	Proficient	Student demonstrated understanding of concept.
4	Advanced	Student demonstrated understanding of concept and answered probing questions at a higher level.

Name ________________________ Period _____ Date ___________ Time __________

Human Biology—Levels of Organization (non-5E) Student Interview Questions

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

1. ____ How do the different levels of organization in your body work together?

2. ____ Which level of organization is most complicated in your body? Why?

3. ____ Do single celled organisms have similar levels of organization? Why or why not?

4. How did this unit help you better understand your world?

5. What activities/lessons do you remember best from our *Human Biology—Levels of Organization* unit?

6. Is there anything else you would like me to know?

Interviewer Rating Scale		
Numerical Score	**Label**	**Description**
1	Below basic	Student demonstrated no understanding of concept or had major misconception(s).
2	Basic	Student demonstrated very limited understanding of the concept or had minor misconception(s).
3	Proficient	Student demonstrated understanding of concept.
4	Advanced	Student demonstrated understanding of concept and answered probing questions at a higher level.

Name __________________________ Period _____ Date ____________ Time ___________

Human Biology—Nervous System (5E) Student Interview Questions

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

1. ____ Please explain how the main parts of your nervous system work together.

2. ____ Please explain how a nerve cell works. You may draw if needed.

3. ____ How do interneurons, motor neurons, and sensory neurons work together?

4. How did this unit help you better understand your world?

5. What activities/lessons do you remember best from our *Human Biology—Nervous System* unit?

6. Is there anything else you would like me to know?

Interviewer Rating Scale		
Numerical Score	**Label**	**Description**
1	Below basic	Student demonstrated no understanding of concept or had major misconception(s).
2	Basic	Student demonstrated very limited understanding of the concept or had minor misconception(s).
3	Proficient	Student demonstrated understanding of concept.
4	Advanced	Student demonstrated understanding of concept and answered probing questions at a higher level.

APPENDIX F

5E LEARNING CYCLE LESSON PLAN TEMPLATE

5E Learning Cycle Unit: ____

Montana Science Content Standard(s): ________________________________

____

____

Stage and Purpose	Teacher Actions	Student Actions	Time Frame
ENGAGE • Create interest and stimulate curiosity. • Provide a meaningful context for learning. • Raise questions for inquiry and science practices. • Reveal students' current ideas and beliefs.			
EXPLORE • Provide experience of phenomenon. • Examine students' questions to test their ideas. • Investigate questions and problems.			
EXPLAIN • Introduce concepts and practices that can be used to interpret data and construct explanations. • Construct multimodal explanations and justify claims in terms based on evidence. • Compare different explanations generated by students. • Review current scientific explanations.			
ELABORATE • Use and apply concepts and explanations in new contexts. • Reconstruct and extend explanations using different models, such as written language, diagrammatic and graphic modes, and mathematics.			
EVALUATE • Provide an opportunity for students to review and reflect on their understanding and skills. • Provide evidence for changes to students' understanding, beliefs, and skills.			

Modified from:
Bybee, R. (2017). *The BSCS 5E Instruction Model: Creating Teachable Moments.* Arlington, VA: NSTA Press, pp. 57, 27.

APPENDIX G

5E LEARNING CYCLE LESSON PLAN RUBRIC

5E Learning Cycle Lesson Plan Rubric **Unit: ______________________________**

Standard(s):

Scoring Criteria:

4	Excellent	All elements of the item are present, complete, appropriate, and accurate with rich details. Another teacher can use the plan (or phase) as written.
3	Good	Most elements of the item are present, complete, appropriate, and accurate, with rich details. Another teacher could use the plan (or phase) with a few modifications.
2	Average	Approximately half of the elements of the item are present, complete, appropriate, and accurate, with some details. Another teacher could use the plan (or phase) with modifications.
1	Poor	Few of the elements of the item are present, complete, appropriate, and accurate, with few details. Another teacher would have to re-write the lesson (or phase) to implement the lesson.
0	Unacceptable	Key elements of the item are not present. Descriptions are inadequate. Plan lacks coherence and is unusable as written.

Overall Lesson:

0 1 2 3 4 Concepts and/or skills selected align with relevant state standards.

0 1 2 3 4 Lesson plan contains objectives that are clear, appropriate, measurable, and align with the assessment/evaluation.

0 1 2 3 4 Materials list is present and complete.

Engage Phase:

0 1 2 3 4 Elicits students' prior knowledge.

0 1 2 3 4 Raises students' interest/motivation to learn.

0 1 2 3 4 Provides opportunities for student discussion/questions (or invites student questions).

0 1 2 3 4 Leads into the exploration phase.

Explore Phase:

0 1 2 3 4 Teacher presents instructions.

0 1 2 3 4 Learning activities are hands-on/minds-on.

0 1 2 3 4 Learning activities are student-centered.

0 1 2 3 4 Learning activities show evidence of student learning (formative/summative assessment.)

Explain Phase:

0 1 2 3 4 Logical transition from explore phase to explain phase.

0 1 2 3 4 Includes teacher questions that lead to the development of concepts and skills. (Draws upon the explore activities/or data collected during the explore activities.)

0 1 2 3 4 Includes mixed divergent and convergent questions for interactive discussion facilitated by teacher and/or students to develop concepts or skills.

0 1 2 3 4 Includes a complete explanation of the concept(s) and/or skill(s) taught.

0 1 2 3 4 Provides a variety of approaches to explain and illustrate the concept or skill.

0 1 2 3 4 Discussion or activity allows the teacher to assess students' present understanding of concept(s) or skill(s).

Elaborate Phase:

0 1 2 3 4 Logical transition from the explain phase to the elaborate phase.

0 1 2 3 4 Activities provide students with the opportunity to apply the newly acquired concepts and skills into new areas.

0 1 2 3 4 Activities encourage students to find real-life (every day) connections with the newly acquired concepts or skills.

Evaluate Phase:

0 1 2 3 4 Lesson includes a summative evaluation.

0 1 2 3 4 The evaluation matches the objectives.

0 1 2 3 4 The evaluation criteria are clear and appropriate.

0 1 2 3 4 The evaluation criteria are measurable.

Comments: ____

____

____

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Modified from:

Goldston, M. J., Dantzler, J., Day, J., & Webb, B. (2013). A psychometric approach to the development of a 5E lesson plan scoring instrument for inquiry-based teaching. *Journal of Science Teacher Education, 24*(3), 527-551.

APPENDIX H

SELF-REFLECTION FORM

Date ______________Unit ______________________________ Circle one: 5E or non-5E

My School Day Overall: **Lesson:**

In general, today I felt:

Stressed	-2	-1	0	1	2	Relaxed
Overwhelmed	-2	-1	0	1	2	Encouraged
Sluggish	-2	-1	0	1	2	Energized
Bored	-2	-1	0	1	2	Curious
Impatient	-2	-1	0	1	2	Patient

My Time Log

Lesson Planning = P Lab Set Up/Tear Down = L Grading = G

	Time
Before School	
Prep	
Lunch	
After School	
Outside of School	

Notes:

____

____

____

____

____

____

APPENDIX I

STUDENT FEEDBACK FORMS

Name ______________________________ Period _____

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in anyway.

During the *Genetics—Changes Over Time* unit, I think Mrs. Dalbey was…

Stressed	-2	-1	0	1	2	Relaxed
Overwhelmed	-2	-1	0	1	2	Encouraged
Sluggish	-2	-1	0	1	2	Energized
Bored	-2	-1	0	1	2	Curious
Impatient	-2	-1	0	1	2	Patient

I answered the questions above in this way because… ____________________________
____
____
____

Name ______________________________ Period _____

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in anyway.

During the *Adaptations and Biomimicry* unit, I think Mrs. Dalbey was…

Stressed	-2	-1	0	1	2	Relaxed
Overwhelmed	-2	-1	0	1	2	Encouraged
Sluggish	-2	-1	0	1	2	Energized
Bored	-2	-1	0	1	2	Curious
Impatient	-2	-1	0	1	2	Patient

I answered the questions above in this way because… ____________________________
____
____
____

Name ______________________________ Period _____

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in anyway.

During the *Human Biology—Levels of Organization* unit, I think Mrs. Dalbey was…

Stressed	-2	-1	0	1	2	Relaxed
Overwhelmed	-2	-1	0	1	2	Encouraged
Sluggish	-2	-1	0	1	2	Energized
Bored	-2	-1	0	1	2	Curious
Impatient	-2	-1	0	1	2	Patient

I answered the questions above in this way because… ____________________________
____
____
____

Name ______________________________ Period _____

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in anyway.

During the *Human Biology—Nervous System* unit, I think Mrs. Dalbey was…

Stressed	-2	-1	0	1	2	Relaxed
Overwhelmed	-2	-1	0	1	2	Encouraged
Sluggish	-2	-1	0	1	2	Energized
Bored	-2	-1	0	1	2	Curious
Impatient	-2	-1	0	1	2	Patient

I answered the questions above in this way because… ____________________________
____
____
____

APPENDIX J

INFORMED CONSENT EXEMPTION FROM PRINCIPAL

POLSON MIDDLE SCHOOL

I, Tim Finkbeiner, Principal of Polson Middle School, verify that the classroom research conducted by Leslie Dalbey is in accordance with established or commonly accepted educational settings involving normal educational practices and that I approve the project. To maintain the established culture of our school and not cause disruption to our school climate, I have granted an exemption to Leslie Dalbey regarding informed consent.

Respectfully,

Tim Finkbeiner
Polson Middle School Principal
October 12, 2017

111 4th AVENUE EAST POLSON, MT 59860 - (406)883-6335 Fax (406)883-6334
www.polson.k12.mt.us

APPENDIX K

INSTITUTIONAL REVIEW BOARD EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-4707
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-4706
cherylj@montana.edu

MEMORANDUM

TO: Leslie Dalbey and Walt Woolbaugh

FROM: Mark Quinn *Mark Quinn CJ*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 16, 2017

RE: *"The Impact of the 5E Learning Cycle on 7th Grade Students' Learning and Retention of Science Concepts"* [LD111617-EX]

The above research, described in your submission of November 15, 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:

_X_ (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.

_X_ (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.