5E INSTRUCTION IN A BIOLOGY CLASSROOM

by

Holly Marie Ingwaldson

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

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ABSTRACT

The purpose of the study was to determine if students learn scientific concepts better from 5E instruction versus traditional science instruction. Two groups of students were taught genetics concepts in accordance with state standards. The non-treatment group received traditional science instruction while the treatment group received a small amount of traditional instruction followed by 5E instruction. Scores from the end of unit test were compared to see if there was a difference between mean and median values. Statistical testing indicated that students learned scientific concepts better when learning through 5E instruction. Students in the treatment group performed better on the test than students in the non-treatment group.

INTRODUCTION AND BACKGROUND

Context of the Study

As each school year passes, I reflect upon my instructional style as a science teacher. I was first introduced to 5E instruction through courses in this master's program, and, immediately upon learning about it, I knew I needed to change my instructional style. I have followed a traditional approach since I started teaching five years ago. My fellow biology teachers helped me get on my own two feet as a beginning teacher by providing me with resources and moral support. However, now that I am more comfortable with the curriculum, I am noticing how disengaging my instruction is. I am not engaging students in or even having students participate in authentic science activities. Rather, they are learning science through lectures and cookie-cutter labs. This was the main reason I decided to conduct my action research project, but also to get a bit out of my comfort zone, to begin to define myself as a science teacher and to have students actually doing authentic science in a high school science classroom.

I currently teach biology and advanced placement (AP) biology at Billings Senior High School in Billings, Montana. Biology is a required course for graduation and is usually taken during a student's sophomore year. As of this school year, it is now offered to freshman who are interested in a medical career and are taking a sophomore level math class. AP biology is an elective course that a student can take their junior or senior year. Billings Senior High School is one of three public high schools in Billings, Montana, and it is the only Title 1 high school in the city. The current enrollment is 1,817 students, of which there are 914 males and 903 females. The student body consists of 71.2% White, 9.4% Hispanic/Latino, 8.2% American Indian or Alaskan Native, 7.9% two or more race categories, 1.8% Black or African American, 1.1% Asian, and 0.4% Native Hawaiian or Pacific Islander students (J. Uhren, personal communication, January 16, 2020).

I conducted this project with my regular biology classes only. The level of scientific understanding and attitudes towards science varies between the students in a course required for graduation, biology, rather than a course that a student willingly chooses to take, AP biology. My project took place during second semester of the school year 2019-2020. Second semester started on January 14, 2020 and my project lasted six weeks, ending on February 25, 2020. I had a total of 82 students who participated in the study, of which 40 were male and 42 were female. I had four students with a 504 Plan and four students with an Individualized Education Program (IEP). The non-treatment group began January 22, 2019 and ended March 1, 2019. There was a total of 63 students, of which 35 were male and 28 were female. Eleven students had IEP's and two had 504 plans. During each six-week study, I had a total of 1,609 minutes with my students.

Focus Question

The focus question for this study was, Do students understand scientific concepts better through 5E instruction compared to traditional science instruction in a high school biology classroom?

Sub-questions included the following:

1. How do students' attitudes towards science change after learning science through 5E instruction?

2. How do students' attitudes and engagement towards 5E instruction compare to attitudes and engagement towards traditional science instruction?

CONCEPTUAL FRAMEWORK

Historical Instructional Models

Instructional models have been around since the start of the 20th century. Many different models have been introduced and modified over the years, but their application and use have recently become more frequent in education. Research has shown that instructional models can help students learn scientific concepts when used effectively. The 5E instructional model has gained much popularity recently in science education. The basis for this model came from a variety of historical models proposed by Johann Herbart, John Dewey and the individuals involved in the Science Curriculum Improvement Study (SCIS) learning cycle (Bybee et al., 2006).

Johann Herbart was a philosopher whose foundation of education was rooted in student interest and conceptual understanding. He believed that, in order to provide effective instruction, students needed to be interested in the subject. In general, student interest comes from direct experiences with the natural world and social interactions. Since science is rooted in the natural world, interest in the subject can be acquired by exploiting student curiosities. In order to gain conceptual understanding, Herbart's instructional model utilized students' prior knowledge to connect new ideas and form an understanding of concepts (Bybee et al., 2006).

John Dewey was a science teacher who based his instructional approach on scientific inquiry, including experience and reflective thinking (Bybee et al., 2006). He believed that knowledge arises from an interaction between the learner and environment. He insisted that prior knowledge should be drawn on in order to further activate the students' learning process. He felt that teaching should be an active process that requires relevance to the learner (Llewellyn, 2013).

The SCIS learning cycle was a program put in place to help children become scientifically literate individuals by helping build science process skills (Cakir, 2017). Robert Karplus was a major contributor to the SCIS learning cycle. He was a physicist who was interested in children's scientific thinking and explanation of natural phenomena, as well as Jean Piaget's work with developmental psychology. Karplus and another colleague, Herbert Thier, created three phases and sequences of the instructional model that lent a hand in the formation of phases in the 5E instructional model. The phases of the SCIS learning cycle included exploration, invention, and discovery. Exploration involves students experiencing phenomena. Invention is when students are introduced to concepts, and discovery is the application of those concepts to new situations (Bybee et al., 2006).

5E Instructional Model

From the historical models mentioned, the 5E instructional model was developed in the early 1960s. It originally was proposed for elementary school science programs but has become increasingly popular with high school science programs (Llewellyn, 2013). It was designed to increase the quality of teaching practice and curriculum (Cakir, 2017). It began from the SCIS learning cycle but incorporated two more phases. The five phases of this instructional model include: engagement, exploration, explanation, elaboration, and evaluation (Figure 1).

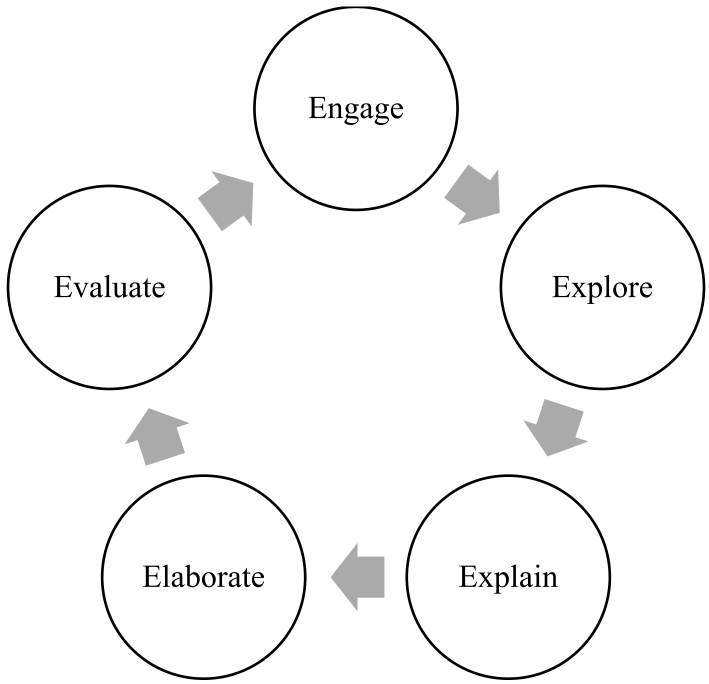

Figure 1. The 5E instructional model (Adapted from Llewellyn, 2013).

The sequence shown in Figure 1 allows the teacher to create a coherent lesson plan that assists students to gain a better understanding of scientific knowledge and skills, and to improve their attitude towards science (Bybee et al., 2006). The 5E instructional model is also known as a learning cycle because it promotes conceptual change. It does so by utilizing a constructivist approach, allowing students a hands-on, minds-on reasoning approach towards the activities they are participating in (Balci et al., 2006). Minds-on skills include critical thinking and active problem solving, collaboration, and communication of findings and ideas (Rodriguez et al., 2019). In constructivism, the learner is filtering information based on existing conceptions in order to construct an updated understanding (Llewellyn, 2013).

During the engagement phase of the instructional model, prior knowledge is assessed and addressed to engage students in a new concept. In order to evoke students' prior knowledge, short activities are used to elicit curiosity and form connections with past and present learning. Activities could include asking a question, defining a problem, or showing a discrepant event to puzzle students and motivate them to participate in the learning activity. Often the engagement phase brings about disequilibrium (Bybee et al., 2006). Disequilibrium occurs in individuals when a newly introduced phenomenon does not fit with existing knowledge. This can cause individuals to give up misconceptions or assimilate and accommodate the information (Llewellyn, 2013).

The second phase of the 5E learning cycle is exploration. During this phase, students are given time to dive into the activities presented in the engagement phase. Activities should have students using prior knowledge in order to generate new ideas. This phase is designed to bring students back towards equilibrium. Activities include problem-solving questions and laboratory work, which may require designing and conducting their own investigation. Overall, the activities should be hands-on and engage students in establishing relationships, observing patterns, identifying variables, and questioning events (Bybee et al., 2006). This phase is a great time to have students engage in inquiry-based labs or guided inquiries. At this time, students are working without direct instruction from the teacher. It allows students to work in collaborative groups and to build upon common experience as they explore the topic. This phase allows students with diverse experiences to share their understandings with their collaborative groups (Llewellyn, 2013).

The explanation phase involves teacher instruction of concepts, processes, or skills. The goal of this phase is for students to gain a deeper understanding of a particular aspect presented in the first two phases. Students should be asked to give explanations from their experiences with the first two phases before the teacher provides scientific explanations (Bybee et al., 2006). The teacher should use common language to explain the scientific concepts the students explored in the first two phases. Then, when details are introduced about the topic, the teacher can add additional verbiage to help students learn the new information using a scientific explanation (Llewellyn, 2013).

Elaboration is the phase used to challenge students' understanding and skills of the concept presented. Additional activities can be used for students to develop a deeper understanding of the topic. This phase has students using concepts during group discussions or other cooperative learning situations to understand a closely related but new situation. This phase is still used for students to further learn the concept (Bybee et al., 2006). Students can continue with self-directed or guided investigations and scientific argumentation can be incorporated during this phase (Llewellyn, 2013).

The final phase of the 5E instructional model is evaluation. This phase brings a close to the lesson or unit (Llewellyn, 2013). It is used to determine the level of achievement a student has made towards the learning objectives. It is important for students to receive feedback on their explanations (Bybee et al., 2006).

The basis for the 5E instructional model aligns with the goals of the Next Generation Science Standards (NGSS) (Bybee, 2015). The NGSS are a model that allows students to participate in science by applying and exploring the science concepts they learn while engaging in scientific practices (McNeill & Berland, 2016). The NGSS consist of three dimensions: Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices. The standards focus on students using science to explain phenomena while engaging in the three dimensions (NSTA, 2016). Lessons using the 5E instructional model are designed with performance expectations in mind. During classroom instruction, learning experiences are sequenced appropriately to aid the learning of science concepts. While learning science concepts, students are engaging in all three dimensions of the NGSS (Bybee, 2015).

Effectiveness of the 5E Instructional Model

Historical research on learning cycles shows its effectiveness in a science classroom. Students who were taught using the learning cycle approach showed greater gains in subject matter knowledge than students who received information in a traditional approach, defined as a lecture followed by an activity. They also developed scientific reasoning skills, such as inquiry and other general science skills, like observing, measuring, and predicting, more so than students who were in a traditional style classroom. Students' attitudes towards science were more positive if the instruction used a learning cycle approach (Bybee et al., 2006).

Similar studies of the 5E instructional model showed that students were more motivated and active in their learning than students in classrooms that were lecture-based. Those exposed to the 5E model had more opportunities to share what they experienced and the knowledge they gained. Overall, student academic achievement is affected more positively by the 5E model than traditional teaching (Cakir, 2017).

METHODOLOGY

Demographics and Treatment

The purpose of the study was to determine if using the 5E instructional model had an impact on student learning. Data was collected during a six-week unit on genetics from two different groups of students taught a year apart. The treatment group consisted of 82 students across four biology classes which received both traditional and 5E instruction. The non-treatment group consisted of 63 students across three biology classes which only received traditional instruction. Data was analyzed to determine if the 5E instructional model helped to improve student scores on the same content test. Data was also collected from the treatment group to determine if students' attitudes towards science improved when learning concepts using the 5E instructional model as compared to traditional instruction. In order to collect data to answer those questions, the genetics unit was split into two mini units. The first mini unit covered basic Mendelian genetics and it was taught using a traditional style of science instruction. The second mini unit was taught using 5E instruction, covering complex genetics and epigenetics. Some strategies used to incorporate 5E instruction included asking questions to engage students in the topic, using case studies for problem solving exploration, and claim-evidence-reasoning lab conclusions for elaboration. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Data Collection and Analysis Strategies

Students in my second semester biology class during the 2019-2020 school year served as my treatment group. Before the unit began, students were given the Genetics Unit Test to serve as a pre-test to gauge what they already knew about genetics (Appendix B). The results were used as a comparison to their post-test scores. The test was analyzed using a paired t-test to compare the averages between the pre- and post-test. The median of each test was also calculated. Both of these statistics helped determine to what extent students gained content knowledge. A two-sample t-test was used to compare the averages of the post-test taken by the treatment group and the non-treatment group from the year prior. The average scores were compared and the median was determined to see if there was a difference between the type of science instruction and content score. Since I used this test with my non-treatment group I didn't alter it for my treatment group. I had extra credit questions which I kept to ensure the results were consistent between the two groups. Because of this, the highest score possible was 109%.

Assessments were given throughout the unit to check in on student understanding. Those assessments were mostly quizzes and they weren't used for data collection purposes for this study. Instead, I used the Directed Paraphrase Assessment after my first 5E lesson to see how the lesson went (Appendix C). Students summarized sex-linked traits and I analyzed their answers for common themes, making sure they were accurate with their information.

To collect data regarding students' attitudes towards science, the Student Pre-Survey was administered at the beginning of second semester, before any genetic content was taught (Appendix D). The Likert survey asked questions regarding student attitudes towards school, science, and different instructional styles. Students responded by choosing strongly disagree (1), disagree (2), agree (3), or strongly agree (4). There were open-ended questions that asked students to identify instructional styles that helped them learn science best. At the end of the six-week unit, students took the Student Post-Survey (Appendix E). The Likert survey was nearly identical to the survey found in the Student Pre-Survey. The median value for each question was analyzed and a Wilcoxon signed rank test was used to compare the median values between the pre- and post-survey. The data was analyzed to determine if students' attitudes towards science changed after learning science through the 5E instructional model. There were additional open-ended questions on the Student Post-Survey that were analyzed for common themes regarding students' attitudes and engagement towards the 5E instructional model.

Lastly, eight students were randomly selected in order to answer six interview questions about their attitudes towards the genetics unit (Appendix F). One female and one male student from each class period were interviewed and their answers were analyzed for common themes. Their names were randomly generated through PowerSchool's random student selector. Two of the questions asked about what the student liked and disliked about the unit. Two of the questions asked about what content the student understood the best and the least from the unit. One question asked about the style of teaching instruction that the student preferred. All of the questions had an elaboration piece so students were explaining their answers. A triangulation matrix was created to summarize the questions of the study and the source of data (Table 1).

Table 1. Data Triangulation Matrix.

Focus Question	Data Source	Data Source
Primary Question: 1. Student Understanding of Concepts	Pre-test and post-test data from Genetics Unit Test	Directed Paraphrase
Sub-Questions: 2. Students' Attitudes Towards Science	Student Pre-Survey and Student Post-Survey data assessing the Likert style questions	Interview Questions
3. Students' Attitudes Towards 5E Instruction	Student Pre-Survey and Student Post-Survey data assessing the open-ended responses for common themes	Interview Questions

DATA ANALYSIS

Results

The results of the Genetics Unit Test indicated that there was a statistically significant difference in student scores based upon instructional style. Scores from two consecutive years were compared using a two-sample t-test. The t-value was 2.97 which was greater than the critical value of +/- 1.645, therefore, there was a difference between the mean score of the two groups. The mean score was higher for the treatment group than the non-treatment group. The treatment group's mean was 84% while the non-treatment group's mean was 74%. The median score was also greater in the treatment group at 87% compared to the non-treatment group at 76% (Figure 2). Overall, 91% of students in the treatment group passed the exam with a D (60%) or higher (*N*=82). In the non-treatment group, 83% of students passed the exam (*N*=63).

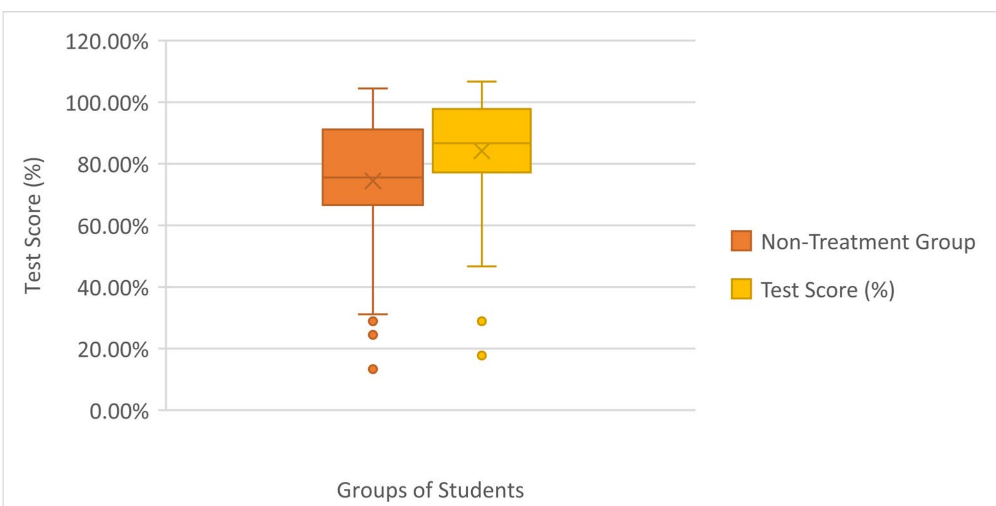

Figure 2. Genetic Unit Test scores from the non-treatment group (*N*=63) and treatment group (*N*=82).

Additional results from the Genetics Unit Test indicated that there was a statistically significant difference in student scores between the pre-test and post-test. (*N*=82). A paired t-test was used to determine if there was a difference in mean scores before and after genetics content was taught. The t-value was -31.77 which was greater than the critical value +/- 1.664, meaning the post-test mean score was greater than the pre-test mean score. On the pre-test, the median score was 29% and the mean score was 30%. The median score on the post-test was 87% and the mean was 84% (Figure 3).

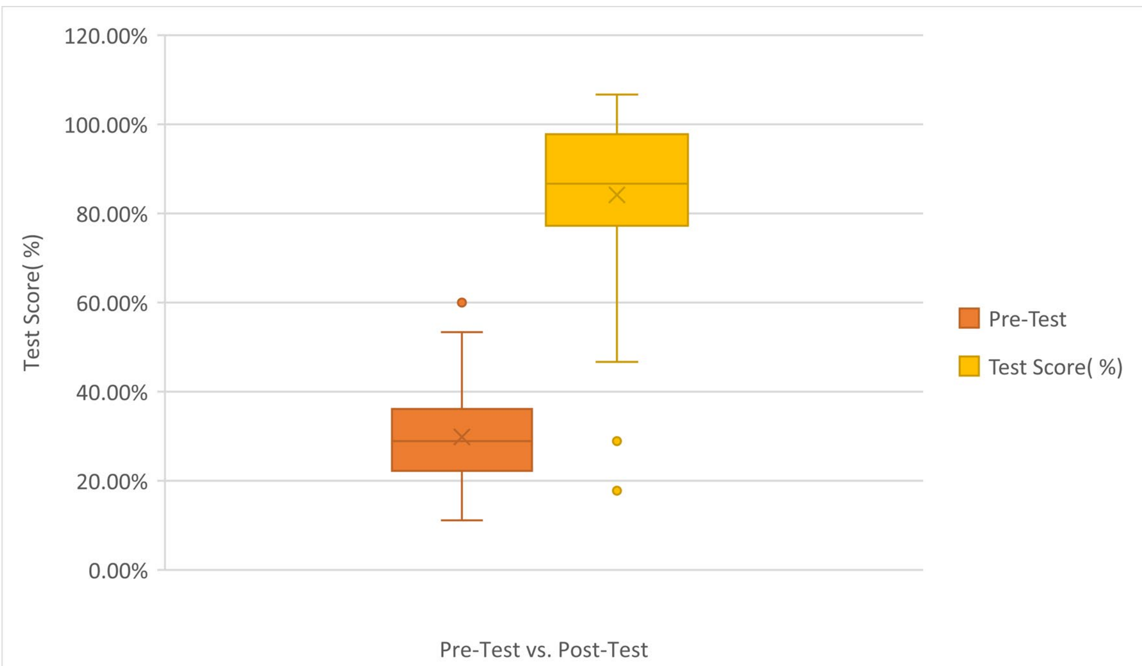

Figure 3. Genetic Unit Test scores from the treatment group before and after content was taught (*N*=82).

The Directed Paraphrase Assessment was analyzed for common themes regarding sex-linked inheritance (*n*=79). The themes included the location of genes on the sex chromosomes, males are more likely to get a sex-linked trait due to having one allele for the trait on the X chromosome, and that females can be carriers of sex-linked traits since they have two alleles for each trait. Forty-three percent of students mentioned that males inherit one X and one Y chromosome while 42% of students mentioned that females inherit two X chromosomes. Thirty-five percent of students mentioned that sex-linked traits are found on the sex chromosomes. Twenty percent of students mentioned that females can be carriers and 19% mentioned that males have a higher chance of getting a sex-linked trait than a female due to the inheritance of one X chromosome (Figure 4).

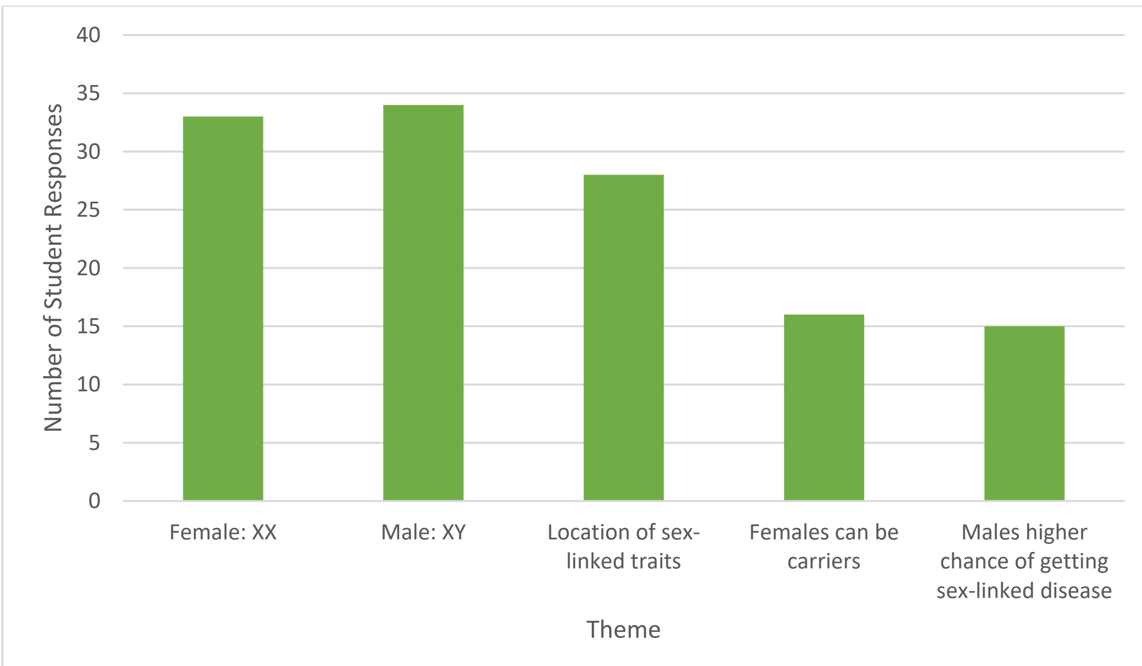

Figure 4. Data collected by themes from the Directed Paraphrase Assessment (*n*=79).

Qualitative data regarding confidence in knowledge of genetics was collected from the Post-Survey. Eight students didn't feel confident in their knowledge of genetics after learning the content (*n*=72). The rest of the students responded positively. One student said, "I feel more confident in my knowledge of genetics than anything else I have done in Biology this year." Another responded, "I feel confident because this is like the first time where I actually get a subject in bio and it shows in my grades."

Another open-ended question on the Post-Survey regarding attitudes towards school, science, and science instruction had some good qualitative data regarding the 5E method (*n*=62). One student said, "Science is a very hard subject for me to learn, but the 5E method helped me get my first A on a test all year." Another said, "Please keep doing the 5E, science is usually my lowest grade, but since you started doing this it is my highest."

Results from the Likert portion of the Post-Survey were analyzed using the Wilcoxon signed rank test to see if students attitudes towards science changed from first semester to second semester by asking about their enjoyment and engagement of the class, including the amount of lab work they experienced (*n*=74). Data from student enjoyment of their first semester science class and their second semester science class had a p-value of 0.0029. The p-value was less than 0.05 indicating that there was a difference in enjoyment from first semester to second semester. Data from student engagement in their first semester science class and their second semester science class had a p-value of 0.0002, which also indicated that there was a difference in engagement between the semesters. Lastly, data from first semester and second semester amount of lab experience was analyzed and a p-value of 0.047 indicated that there was a difference in the likability of the amount of lab experience (Figure 5).

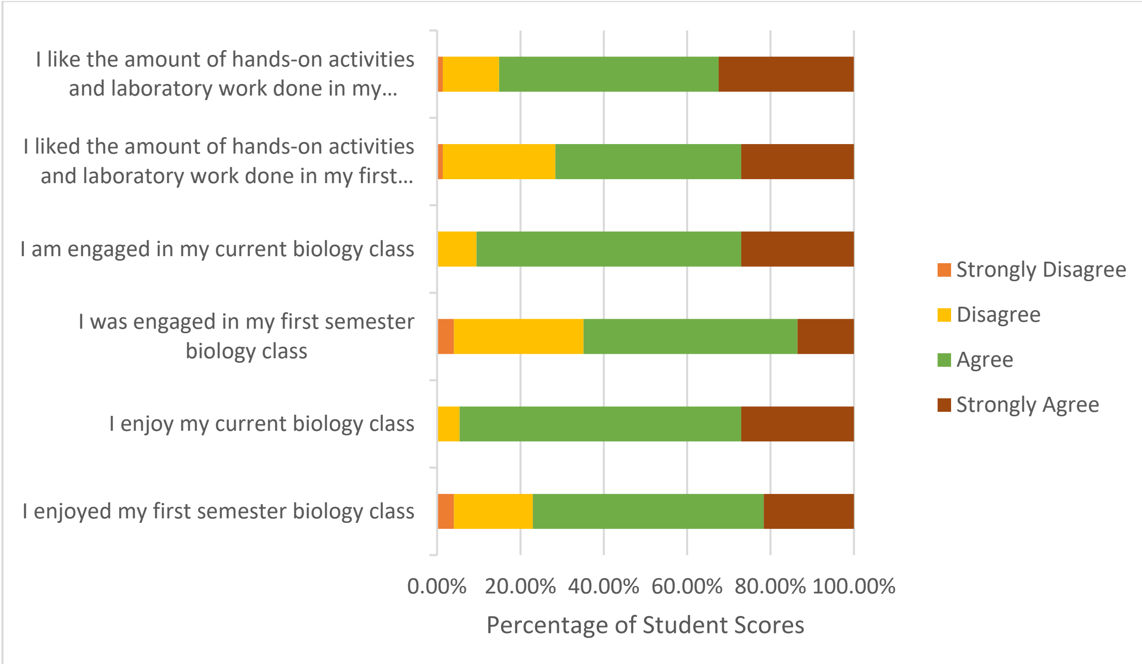

Figure 5. Likert data from the Post-Survey (*n*=74).

From the Post-Survey, 69.4% of students said they learned genetics concepts better from 5E instruction while 30.6% learned better from traditional instruction (*n*=74). When asked which instructional method was more engaging, 68.9% said 5E instruction while 31.1% preferred traditional instruction. Students were randomly selected to answer interview questions regarding what they learned and the type of teaching instruction (*n*=8). Of the sample interviewed, 87.5% preferred 5E instruction. When asked why students thought they learned best with the 5E instruction, one said “We went deeper into the content. We did stuff then you explained it and we covered more after that.” Another student responded, “I think it got us more involved with learning, instead of us just listening and writing stuff down.”

CLAIM, EVIDENCE, AND REASONING

Claims from the Study

The results of the Genetics Unit Test indicated that students learned genetic concepts better through 5E instruction compared to traditional science instruction. The non-treatment group received traditional instruction while the treatment group received a small amount of traditional instruction, followed by 5E instruction. The mean and median test scores were greater with the treatment group. The groups of students were not the same students, so there could have been a difference in data due to that.

The treatment group took an identical pre- and post-test to determine if students gained genetics content knowledge. One student passed the pre-test while all the remaining students scored under 59% (*N*=82). The one student that passed, transferred down from honors biology at semester. After the completion of the unit, all but 8.5%, passed the post-test. No students digressed in their content knowledge. Data from the Post-Survey had positive comments about gains in student knowledge and attitudes towards the 5E instructional model.

The Directed Paraphrase Assessment was used to collect data to see what students understood from the first 5E lesson on sex-linked traits. It was assessed for common themes. Most students didn't address the themes I was looking for. Some didn't even talk about sex-linked traits, but rather genetics information in general. Some were close to the theme but missed one little detail. I don't have any data to compare this to so I don't know if they learned the content better than the year prior. Eight of the students had errors, which I addressed to them (*n*=79). If I were to do this again, I would be more specific with the question I asked, rather than having such an open-ended question.

The Post-Survey data was used to analyze students' attitudes towards science. Three questions were analyzed to see if there was a difference in mean scores. The data was paired since the survey asked students about both first semester and second semester attitudes. Seventy-two percent of the students surveyed had me first semester as well. All of the biology teachers at my school typically teach with a traditional style of instruction. They may incorporate parts of 5E instruction but aren't intentional with using it full time. The first question asked if the student enjoyed their first semester biology class, which was compared to another question that asked if they enjoyed their current, second semester, biology class. The data indicated that there was a difference in the means, students agreed that they were enjoying their second semester biology class better than their first. The second pairing asked the student if they were engaged in their first semester biology class and then if they were currently engaged in their biology class. Again, the data indicated that there was a difference in the means, students agreed that they were more engaged in their current biology class. The last pairing asked the student if they liked the amount of hands-on lab work in their first semester biology class and then in their current biology class. The statistical test indicated there was a difference, however, the p-value was marginal. Students were enjoying the amount of hands-on lab experience in their second semester. It would be interesting to ask them again at the end of the semester, instead of the end of the first unit of three units covered. Overall, students' attitudes towards science improved from first semester to second semester as they began learning with 5E instruction.

As for student attitudes towards 5E instruction, 69% of my students enjoyed it over traditional instruction. Some negative feedback I received about it mentioned that it was too repetitive with the E's. This could have been because I had many small units that had all 5E's incorporated in it. Overall, students enjoyed using hands-on activities to learn as well as problem-solving prior to me giving direct instruction.

Value of the Study and Consideration for Future Research

I was very pleased with the test scores of the students in my treatment group. To me, 5E instruction helped me clarify the topics since students were engaged and exploring them more so than traditional instructional methods. I did feel pressure of the six-week time constraint that I didn't have teaching this unit in a traditional style. Some topics, I feel, weren't covered as well with my treatment group since I was beginning to run out of time. Looking back, I would like to try this a little differently. I would like to have two groups of students and two different units. One group of students receiving traditional instruction for one unit and then 5E instruction for the next unit. While the other group is receiving opposite instruction from the first group. I would compare test scores to see if there was a difference in content knowledge gained from each teaching style. That way, the same set of students would be exposed to both types of instruction and I could also collect data regarding their attitudes towards each instructional style.

Impact of Action Research on the Author

I really enjoyed conducting this action research project in my classroom and I learned so much about myself from it. I am glad I was able to try something new and that my students enjoyed the process as well. I was able to reflect upon my previous teaching style and plan to be more intentional with my lessons in the future following the 5E model. There have been times when I have started a new unit with a lecture when I should have had students explore the concepts before I gave them the information. I plan to find more lessons that explore biological concepts and provide more hands-on learning. The 5E model is a great way for students to get involved in doing and learning science rather than sitting and learning science.

The knowledge I have gained from conducting an action research project will carry with me for the rest of my teaching career. I will continue to carry out this type of project, more informally, for the benefit of my students and I. As a teacher, I want to be the best that I can be for my students in order for them to achieve success in science and other classrooms. In our ever-changing world, I need to adapt to new methods of instruction that work with the population in front of me. I am proud that I was able to carry out such a project, and I look forward to continuing to better myself as an educator.

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APPENDICES

APPENDIX A

IRB EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

2155 Analysis Drive
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-4706
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: Holly Ingwaldson and John Graves

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

DATE: November 19, 2019

RE: *"The Effects of 5E Instruction in a Biology Classroom" [HI111919-EX]*

The above research, described in your submission of November 18, 2019, 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; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

___ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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

APPENDIX B

GENETICS UNIT TEST

Genetics Unit Test

Multiple Choice-Vocabulary

1. The study of environmental influences on gene expression that occurs without a DNA change
   a. epistasis b. epigenetics c. genetics d. mutation
2. An organism that has two different alleles for a gene is called __________.
   a. dominant b. recessive c. homozygous d. heterozygous
3. A ____________ allele is one that is masked when a dominant allele is present.
   a. dominant b. recessive c. homozygous d. heterozygous
4. Genotype refers to _____________________.
   a. an organism's physical appearance
   b. any of the alternative forms of a gene that occurs at a specific place on a chromosome
   c. an organism's genetic makeup
   d. a trait that is expressed when 2 different alleles are present
5. Phenotype refers to ____________________.
   a. an organism's physical appearance
   b. any of the alternative forms of a gene that occurs at a specific place on a chromosome
   c. an organism's genetic makeup
   d. a trait that is expressed when 2 different alleles are present
6. An organism that has two of the same alleles for a gene is called ______________.
   a. dominant b. recessive c. homozygous d. heterozygous
7. Any of the alternative forms of a gene that occurs at a specific place on a chromosome is called ___________.
   a. genotype b. phenotype c. allele d. trait
8. A sequence of DNA that codes for a protein
   a. trait b. gene c. allele d. cross
9. A cell that makes up all of the body tissues and organs
   a. sex cell b. gamete c. egg d. somatic cell
10. Humans have 23 pairs of chromosomes. One pair determines your gender and are called_____________.
    a. chromosomes b. sex chromosomes c. autosomes d.centrosomes
11. A person that has a recessive allele for a genetic disorder, but does NOT show the disorder is called a _____________.
    a. carrier b. dominant c. recessive d. homozygous
12. Incomplete dominance is when __________________.
    a. one allele is dominant over the other
    b. neither allele is dominant over the other, and therefore both are fully expressed
    c. traits are passed down to offspring on the sex chromosomes
    d. one allele does not completely dominate another allele and therefore results in a new phenotype which is a blend of the two homozygous phenotypes
13. Skin color is a ___________ trait, because it is produced by many genes.

Genetics Unit Test

a. sex-linked b. polygenic c. inherited d. recessive

14. What is the chart that can help trace the phenotypes and genotypes in a family to determine whether people carry recessive alleles?
    a. Punnett square b. karyotype c. genetic map d. pedigree
15. All of an organism's genetic material
    a. genotype b. phenotype c. gene d. genome

Matching- Blood Lab

A. Antibodies
B. O-
C. AB+
D. B
E. A
F. A and B
G. --
H. +-
I. Agglutination
J. Erythrocytes
K. Antigens
L. AB-
M. none

16. What is it called when RBC's clump together and interfere with blood circulation.
17. Proteins found on the cell membrane of red blood cells that determines the blood type.
18. Proteins that fight specific antigens and protect the body against foreign invaders.
19. Universal Donor blood type.
20. A person with A blood has what type of antigens?
21. A person with O blood has what type of antigens?
22. A possible genotype of a person with positive blood.
23. Genotype of the mother that could fight against her baby if her baby is Rh-positive.

Short Answer

Sickle cell disease is recessive. Cross a man and a woman who are both carriers of the trait. Imagine they both live in an area with Malaria. A= normal S= sickle

24. If an individual is a carrier, their blood has both normal and sickle-shaped red blood cells. This is an example of which type of inheritance?
25. What is the probability that they will have a child with the favorable genotype for sickle cell disease in a Malaria infested area?

Four o'clock flowers petal color follows an incomplete dominance inheritance pattern. A red 4 o'clock flower is crossed with a white 4 o'clock flower.

26. What is the color of their offspring?
27. Cross two heterozygous flowers. What is the probability that they will have white flowers?

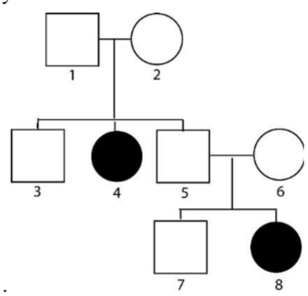
A man who has blood type A is crossed with a person who has blood type B.

28. Is it possible for them to have a child with O type blood? Show you Punnett square.
29. Which blood type shows codominance? Why?

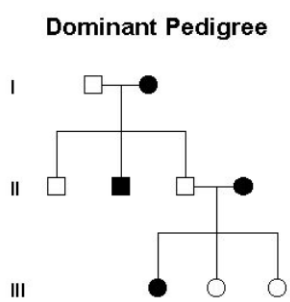
Genetics Unit Test

29. Which blood type shows codominance? Why? Colorblindness is a recessive sex-linked trait. A woman who is a carrier has children with a man who is colorblind.
30. How many females will be colorblind? Keep this in a fraction, do not simplify.
31. Who is responsible for giving their son colorblindness? Explain.

32. What type of inheritance(dominant, recessive, sex-linked)is the following trait? Explain how you know



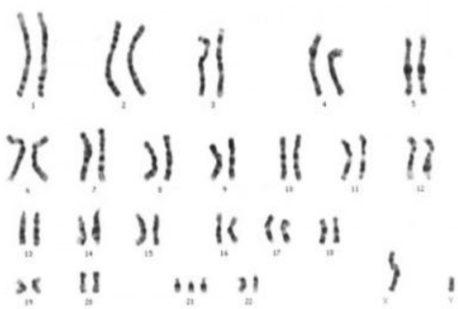
33. Write in the genotypes for each individual in the following pedigree.

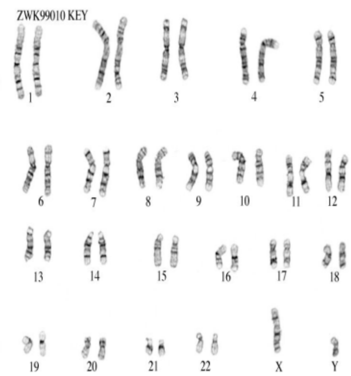


34. Create a pedigree with the following information. Mom has freckles but Dad doesn't. They have three kids- Stella has freckles, Bruce has freckles, and Carla doesn't have freckles.

Genetics Unit Test

35. What do the two pictures below show? (the vocabulary term)
36. Compare the two pictures.
37. Contrast the two pictures.





38. Name five environmental factors that can influence your gene expression.

Extra Credit

1. Why are sex-linked traits more common in males than females?
2. Name a gamete.
3. How many chromosomes are in a gamete?
4. What is the name of the pictures on this page? (different term than #35)

APPENDIX C

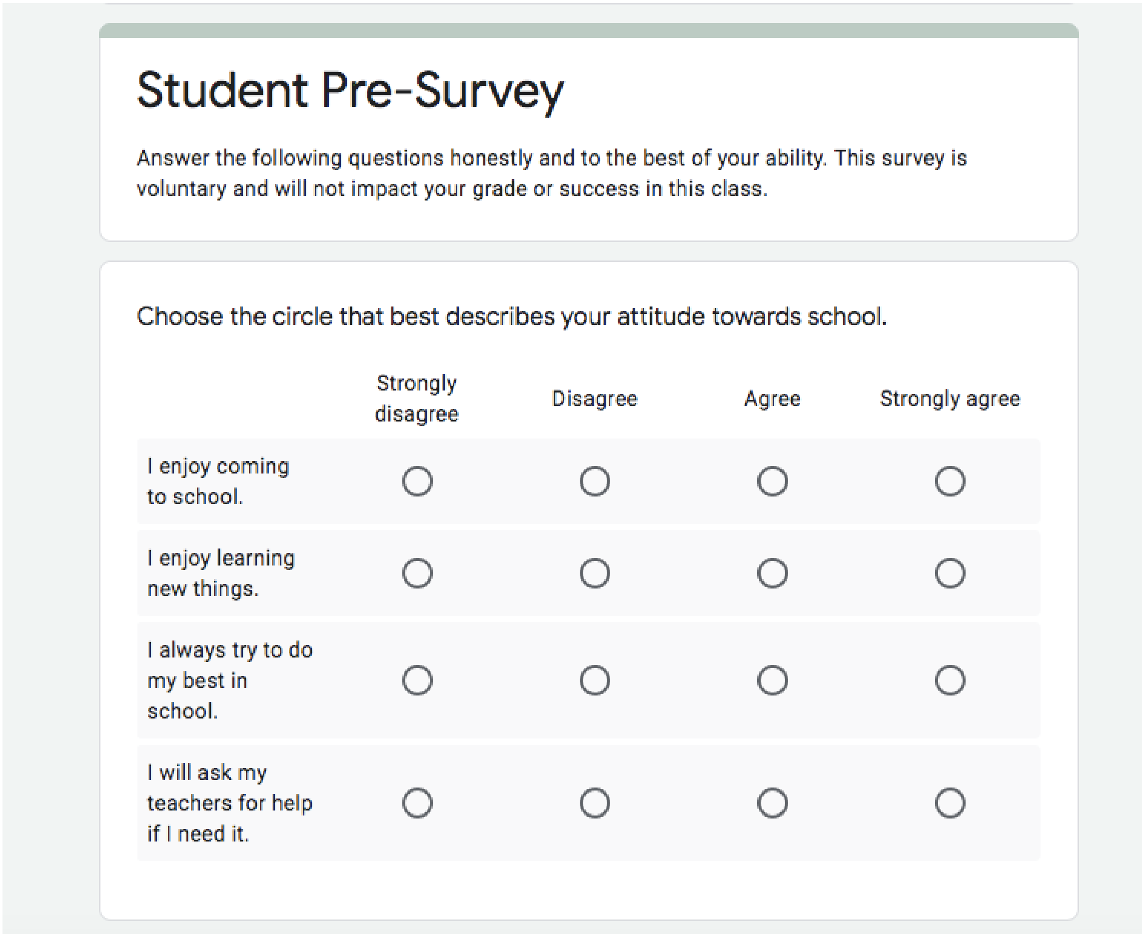
DIRECTED PARAPHRASE ASSESSMENT

Directed Paraphrase

Imagine you are reviewing for an upcoming quiz with a college student. In five sentences, explain what you know about sex-linked inheritance.

APPENDIX D

STUDENT PRE-SURVEY



Student Pre-Survey

Answer the following questions honestly and to the best of your ability. This survey is voluntary and will not impact your grade or success in this class.

Choose the circle that best describes your attitude towards school.

	Strongly disagree	Disagree	Agree	Strongly agree
I enjoy coming to school.	○	○	○	○
I enjoy learning new things.	○	○	○	○
I always try to do my best in school.	○	○	○	○
I will ask my teachers for help if I need it.	○	○	○	○

Choose the circle that best describes your attitude towards science.

	Strongly disagree	Disagree	Agree	Strongly agree
I enjoyed my first semester biology class.	○	○	○	○
I was engaged during my first semester biology class.	○	○	○	○
I liked the amount of hands-on activities and laboratory work done in my first semester biology class.	○	○	○	○
I would like to pursue a career in a scientific field.	○	○	○	○
I feel prepared for the Genetics Unit Test	○	○	○	○

Choose the circle that best describes your preferred learning style.

	Strongly disagree	Disagree	Agree	Strongly agree
I enjoy when teachers use lectures to present information.	○	○	○	○
I enjoy reading a textbook to learn information.	○	○	○	○
I enjoy using problem-solving skills to learn information.	○	○	○	○
I enjoy engaging in group discussion to learn information.	○	○	○	○
I enjoy using worksheets to learn new information.	○	○	○	○
I enjoy using hands-on activities to learn new information.	○	○	○	○

What instructional methods help you learn scientific concepts best? (For example- teacher lectures and notetaking, reading and taking notes on your own, laboratory work, in-class activities like quizlet live, group work, or anything else)

Your answer

What was something your first-semester biology teacher did that helped you learn scientific concepts best?

Your answer

Is there anything else you would like me to know regarding your attitude towards school, science, and science instruction?

Your answer

Submit

APPENDIX E

STUDENT POST-SURVEY

Student Post-Survey

Answer the following questions honestly and to the best of your ability. This survey is voluntary and will not impact your grade or success in this class.

Choose the circle that best describes your attitude towards school.

	Strongly disagree	Disagree	Agree	Strongly agree
I enjoy coming to school.	○	○	○	○
I enjoy learning new things.	○	○	○	○
I always try to do my best in school.	○	○	○	○
I will ask my teachers for help if I need it.	○	○	○	○

	Strongly disagree	Disagree	Agree	Strongly agree
I enjoyed my first semester biology class.	○	○	○	○
I enjoy my current biology class.	○	○	○	○
I was engaged during my first semester biology class.	○	○	○	○
I am engaged during my current biology class.	○	○	○	○
I liked the amount of hands-on activities and laboratory work done in my first semester biology class.	○	○	○	○
I like the amount of hands-on activities and laboratory work done in my current biology class.	○	○	○	○
I would like to pursue a career in a scientific field.	○	○	○	○
I felt prepared for the Genetics Unit Test	○	○	○	○

Choose the circle that best describes your preferred learning style.

	Strongly disagree	Disagree	Agree	Strongly agree
I enjoy when teachers use lectures to present information.	○	○	○	○
I enjoy reading a textbook to learn information.	○	○	○	○
I enjoy using problem-solving skills to learn information.	○	○	○	○
I enjoy engaging in group discussion to learn information.	○	○	○	○
I enjoy using worksheets to learn new information.	○	○	○	○
I enjoy using hands-on activities to learn new information.	○	○	○	○

What instructional method helped you learn genetics concepts better?

- ○ Traditional instruction- Basic Mendelian Genetics
- ○ 5E instruction-Complex Genetics and Epigenetics

What instructional method were you more engaged in?

- ○ Traditional Instruction- Basic Mendelian Genetics
- ○ 5E Instruction- Complex Genetics and Epigenetics

What did you like BEST about my instruction during our Genetics Unit?

Your answer

What did you LEAST like about my instruction during our Genetics Unit?

Your answer

What could I do to improve my instruction during our Genetics Unit?

Your answer

Do you feel confident in your knowledge of genetics? Explain.

Your answer

Is there anything else you would like me to know regarding your attitude towards school, science, and science instruction?

Your answer

Submit

APPENDIX F

POST-UNIT INTERVIEW QUESTIONS

Post-Unit Interview Questions

Answer the following questions honestly and to the best of your ability. This survey is voluntary and will not impact your grade or success in this class.

1. What did you like best about the genetics unit?

   Why?

2. What did you like least about the genetics unit?

   Why?

3. What genetics content do you feel like you understand the best?

   Why do you think that is?

4. What genetics content do you still not understand that well?

   Why do you think that is?

5. What style of teaching instruction do you learn science concepts best with? The traditional style instruction like our basic Mendelian genetics unit or 5E instructional style like our last two mini-units?

   Why do you think you learn best with that method?

6. Do you have any additional thoughts or suggestions that you could give me to improve my teaching style?