EFFECTS OF INCORPORATING SELECTED NEXT GENERATION SCIENCE STANDARD PRACTICES ON STUDENT MOTIVATION AND UNDERSTANDING OF BIOLOGY CONTENT

by

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DEDICATION

I would like to dedicate this paper to three people who have encouraged and helped me throughout this entire project. The first is my wife Theresa (Teri) Rowland without whom I would never have entered the program. She not only encouraged me to pursue my master's degree, but also provided encouragement throughout the program without which I would have likely abandoned the effort. She also provided key assistance not only in the completion of all the charts and graphs, but also assisted in proper statistical analysis of the results. Second, Diana Paterson, a truly wonderful individual who is always willing to assist the students in any manner she is able and who has made my participation in the program both pleasant and enjoyable. And finally, John (Terrill) Paterson, a kindred spirit who has been both my instructor and teacher's assistant of several courses throughout the program, and has continuously encouraged me to move forward and has ultimately become a friend.

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ABSTRACT

Students of this day and age often show a lack of interest and engagement in science, as evidenced by a lack of motivation and academic performance. This project focused on the use of selected Next Generation Science Standards practices; developing and using models, using mathematics and computation thinking, and engaging in argument from evidence to aid in helping them understand biology concepts and in motivating and engaging them. The effects of using these practices on instructor engagement and motivation as well as student's perception of the instructor caring about them were also considered.

This project investigated the effects of incorporating the chosen practices as compared to a traditional teacher-centered behaviorist classroom in a general biology course at a moderately sized high school in Wyoming. The effects of incorporating the chosen practices was assessed by comparing two units on the molecular basis of genetics and genetic principles taught using the selected NGSS practices to a traditionally taught unit on bacteria using pre and postintervention assessment data. The initial unit lasted for two weeks, the unit on the molecular basis of genetics lasted for five weeks, and the unit on genetic principles lasted for four weeks. Students completed pre and post intervention target assessments and concept surveys on their perception of understanding. Some students also completed in-depth interviews with the instructor about both the content and the methods of learning.

Additional forms of data collection were employed during all three units to determine the effect on student engagement and motivation, including field notes, pre and postintervention nonconcept interviews, and pre and postintervention biology engagement/motivational questionaires. Effects on the instructor's teaching and motivation were determined through the use of field notes, pre and postintervention surveys, and nonintervention and intervention observations by a colleague. The effects on students' perception of instructor caring was assessed using field notes and reflective journaling, pre and postintervention surveys and student quotes from pre and postintervention surveys.

The results showed improvement in both student conceptual understanding and student motivation and engagement. Results also showed an improvement in the instructor's engagement and motivation. A review of data regarding the effects of incorporating the selected NGSS practices on students' perception of instructor care for them revealed a lack thereof and the results were inconclusive.

INTRODUCTION AND BACKGROUND

Two years ago, my principal called me to her office; in looking through student enrollment for the following year, she noticed that enrollment numbers for my courses were lower than those of other science teachers. She felt that this low enrollment was in part a result of student perception that I was a very difficult teacher and that I did not care about my students. Initially angry over what I felt were inaccurate assertions, I eventually came to terms with the situation and began to reflect on what I could do differently to change these perceptions.

Upon reflection, I realized that over the last few years, I have noticed an increasing lack of student interest and engagement, as evidenced by a lack of motivation and academic performance on the part of biology students. According to Wlodowski (1991), motivation is one of the most important factors in successful accomplishment. Engagement is defined by Howes (2003a) as “the students’ active interaction with the learning process” (p. 2).

Over the course of the summer, while attending the Geology of Glacier class with Dr. John Graves through Montana State University, several other students and I were discussing the Next Generation Science Standards (NGSS) with John and he pointed out how he thought incorporating the practices identified in NGSS should motivate as well as help students achieve greater success on state and national assessments. I decided to investigate whether incorporating NGSS into my classroom would help to motivate and engage all students in biology and in turn this should change their perceptions regarding myself as an instructor.

By researching, I learned that NGSS promotes eight practices. According to the National Research Council, these practices are behaviors that scientists engage in as they investigate and build models and theories about the natural world, and engaging in these practices will help students become successful analytical thinkers that are prepared for both college and careers (NRC 2012). According to Bybee (2012), these scientific and engineering practices have significant implications for life science programs and classroom practices. Krajeik and Merrit (2012) proclaimed that these practices will provide “a different breed of high school graduates who will view science as an ‘effective method of inquiry’ and who will serve as productive 21st century citizens to create a sustainable planet” (p. 41). I determined that the practices of NGSS might well be the tool that could be used to remedy my situation.

While I have always incorporated some of these practices to at least some degree, I decided to redesign two units for my project focusing on Heredity: Inheritance and Variation of Traits across generations, to robustly incorporate three of the practices identified within NGSS.

I teach biological sciences at Sheridan High School (SHS) in Sheridan Wyoming. The school serves approximately 920 students, predominately Caucasian, over four grade levels, with approximately one third of the student body identified as being at risk of failing to graduate. I teach a total of 5 classes on three different subjects related to the biological sciences. The students who participated in my capstone project were the members of my third period biology class consisting of 20 students; 1 freshman, 16 sophomores, 2 juniors, and 1 senior, of which 11 were male and 9 were female.

The focus question of my project was: what are the effects of incorporating three specified practices, such as developing and using models, using mathematics and computational thinking, and engaging in argument from evidence, of NGSS on students' understanding of biological concepts? Asking this question led to the following subquestions: what are the effects of incorporating these practices of NGSS on students' engagement and motivation towards biology; what are the effects of incorporating these practices of NGSS on my teaching and motivation as a science instructor; and what the effects of incorporating these practices of NGSS were on students' perception of instructor caring?

I had noticed that teachers today face two major frustrations, a lack of motivation in their students and being overwhelmed by the continuous introduction of the next best idea in education. Given that NGSS is the next best idea and little research on its implementation yet exists, I felt that this project would provide beneficial information to other educators who are faced with the task of figuring out how to motivate and engage their unmotivated students while incorporating the practices of NGSS into their curriculum. While the immediate goal was to increase the interest and engagement of unmotivated students and thereby improve their academic performance, through this project, I also hoped to shift student perception of science from that of a ready-made body of knowledge, to that of an effective method of inquiry. Perhaps most importantly to myself, I hoped to change students' perceptions of me as a difficult instructor who does not care about his students.

To help design and implement this project, my support team included my "critical friend" and wife Teri Rowland, who served both as my initial editor and critic, and provided much needed technological and statistics expertise, and support throughout the research and writing process. My committee chair was Dr. Peggy Taylor, Montana State University Masters of Science in Science Education (MSSE) Program Director. My project advisor Dr. Jewel Reuter, has provided guidance, direction, and support from design to implementation. My MSU reader; John (Terrill) Patterson of the Masters of Science in Science Education program, served as the final reviewer and provided constructive criticism in the final stages. Aaron Kessler, biology coinstructor at SHS observed one class during each phase of the project to provide feedback on student and instructor attitude and engagement. Dirlene Wheeler, SHS principal who also provided support throughout the project.

CONCEPTUAL FRAMEWORK

Bell, Bricker, Tzou, Lee, and Van Horne (2012) point out that the NRC's publication, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2012), provides the framework for the NGSS, and places unprecedented focus on the practices involved in doing scientific and engineering work. According to Bell et al., the intent behind the practices is to engage students in sensible versions of the actual cognitive, social, and material work that scientists do.

NGSS identifies eight scientific and engineering practices recommended for use in science classrooms. These practices include; asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information. The framework proposes that actually doing science and engineering will capture student interest, make students' knowledge more meaningful, and embed it more deeply into their worldview (NRC, 2012). While NGSS calls for inclusion of all eight practices, for simplicity and effectiveness, my project focused on only three; developing and using models, using mathematics and computational thinking, and engaging in argument from evidence.

Of all the practices identified in the NGSS, Campbell, Neilson, and Oh (2013) point out that "helping students develop and use models has been identified by many as an anchor. In instruction, disciplinary core ideas, crosscutting concepts and scientific practices can be meaningfully situated around modeling" (p. 35). According to Gilbert and Boulter (2000), a model is a representation of an idea, object, event, process or a system. Mayer, Damelin, and Krajcik (2013) point out that within NGSS, "models include physical representations, conceptual relationships among elements of a system, and simulations, and that models can be used to explain a broad range of phenomena" (p. 57). The constructivism approach to learning proposes that students' construction of knowledge is influenced strongly by their social environment and that they learn science by a process of constructing, interpreting and modifying their own understanding of reality based on their experiences (Yore, 2001). For students to successfully develop a conceptual understanding in science, Coll, France, and Taylor (2005) concluded that they need to be able to reflect on and discuss their understanding of these concepts as they are developing them. Therefore, allowing students to construct and modify models as their understanding of the content changes can provide them the opportunity to develop that deeper conceptual understanding. In fact, in reflecting on a life science lesson taught to fifth graders on pyramid models of trophic levels Abell and Roth (1995) found that enabling students to construct and critique their own models effectively supports conceptual development outcomes.

It has been stated that students not only need to learn how models are constructed, but also how models in science are debated and tested (Gilbert & Boulter, 2000). To successfully incorporate scientific argumentation into model construction and use, there must first be an understanding of what scientific argumentation consists of. Scientific argumentation is defined by Norris, Philips, and Osborne (2007) as individuals attempting to support, challenge, or refine a claim on the basis of evidence. Mayes and Koballa (2012) propose that constructing viable arguments and critiquing the reasoning of others emphasizes justifying claims within that argument by grounding them in evidence (e.g., mathematical or scientific theories) accepted by the scientific community. Mayer et al., showed how using models of electrostatic interaction with their ninth through twelfth grade students supports the practice of arguing based on evidence. Jimenez-Aleixandre, Rodriguez, and Duschl (2000) in their study on ninth-grade life science students in Spain concluded that when students are given the opportunity to engage in scientific argumentation, they learn not only conceptual comprehension, but certain aspects of science itself.

Research has also shown that to increase the motivation and engagement of students, learning must be made relevant to student learners by building on their understanding and use of scientific knowledge, ideas and the inquiry process by providing opportunities for active scientific inquiry, discussion, and debate among students. Yager (1991) points out that learning is an active process occurring within and influenced by the learner, and thus learning does not depend on what the teacher presents (p. 8). With today's emphasis on student learning rather than on teaching, students must be actively engaged in the learning process. Keeping in mind that scientific models can be mathematical as well, consisting of equations or functions, tables of data, graphs or even statistical displays, Mayer et al., (2013) points out that “to support students’ engagement in scientific practices, teachers should create an environment full of rich phenomena and meaningful data from which students build initial models” (p. 57). Further, “teachers need to provide students more opportunities to craft scientific arguments and participate in discussions that require them to support and challenge claims based on evidence” (Sampson, Enderle, & Grooms, 2013). In a study conducted on Korean high school students in an extracurricular science club, Oh and Oh (2013) reported that modeling can be a means to teach science in an authentic manner and that the use of such alternative forms of representation can help motivate students who have difficulty with verbal explanations. A study conducted in Croatia on 1240 students ranging from age 10 to 14 engaging in a variety of subjects, focused on student participation using constructivist activities, found that 76% of students expressed the opinion that these types of lessons make the learning process “better and easier” (Rukavina, Zuvic-Butorac, Ledic, Milotic, & Jurdana-Sepic, 2012, p. 17). While surprisingly little direct quantitative data yet exists to support the assertion that engaging in these practices will in fact capture student interest, make their knowledge more meaningful, or embed it more deeply, Day (2012) points out that “teacher presence, while a necessary condition for successful teaching, is however not sufficient to achieve optimal learning. Students themselves must also be willing and able to be present” (p. 18). While much of my own experience has primarily been that of conveying knowledge directly to students, studying the practices of NGSS has helped me to realize that this is one of the least effective methodologies for promoting learning, and that I need to relinquish some control of my classroom and begin allowing students to take more responsibility for their own learning.

The implications of making this shift on my own motivation as a teacher are also implicate in the research. Passmore, Coleman, Hortan, and Parker (2013) found that when units are formulated around the practices identified in NGSS, students not only score better when tested on the material, but also can apply their understanding to subsequent units, guiding both teacher and student interactions. Shawer, Gilmore, and Banks-Joseph (2008) found in researching the impact of teacher curriculum approaches on a group of mixed college students studying English as a foreign language, that teachers that incorporate these constructivism type lessons realize better results in student learning and see higher motivation on the part of the students. This in turn motivated the teachers to develop additional materials following this format. Guzel (2011) in his study on physics teachers makes the point that "Improving motivation will increase the effectuality and efficiency in learning and teaching" (p. 1047) and that "motivation of teachers is extremely important for both motivation of students in the classroom and advanced education reforms that might be realized" (p. 1047). If these practices are used to engage and motivate students, Bybee (2013) claims that "NGSS likely will influence K-12 science teaching for at least a decade, longer if recent history is any indication" (p. 32).

A study conducted school wide on middle school students in central Florida determined that project management techniques used by teachers in the classroom contributes significantly to students' perceptions of teachers as caring (Howes, 2003b). Shawer et al., (2008) found that not only were students and teachers more motivated by using these types of activities, but that the students' perception of teachers who worked to develop additional curricular activities, was that they were more caring than those who simply followed the textbook.

In summary, while this research provided me with an understanding of the theory of what is involved in incorporating NGSS practices into the classroom, producing lessons, which match with this theory and incorporate the ideals identified within these practices, remains a significant challenge. By building upon those practices, I hoped to begin the process of converting my teaching into a true NGSS-based classroom. As indicated in the literature, creating lessons for biology that incorporated developing and using models, mathematics and computational thinking, and engagement in argument from evidence should increase the student's understanding of biological concepts, as well as their engagement and motivation within the biology classroom. Also, as indicated in the literature, incorporating these practices modified my role from a disseminator of information to a facilitator of learning which should increase my own motivation to continue to make changes in curriculum and in turn result in a change of students' perception of me as an uncaring instructor.

METHODOLOGY

Project Treatment

For my capstone, I used three consecutive units. The first unit on bacteria was taught with my usual behaviorist curriculum. The second and third units on the molecular basis of genetics, and genetic principles respectively, were specifically designed to include NGSS through the incorporation of the following three practices; developing and using models, using mathematics and computational thinking, and engaging in argument from evidence. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained. I worked with these units over a timeline of eleven weeks, included as Appendix A. During this project, to assess outcomes based on implementing the NGSS practices, data were collected from the nonintervention and intervention units for comparison.

The nonintervention unit took place over a two week period and covered bacteria. The students completed a preunit target assessment, included as Appendix B, to determine what they initially knew about the topic. Students were introduced to bacteria via traditional behaviorist learning activities; reading assignments from the text (Miller & Levine, 2010) were completed, lectures were given over the material via PowerPoint presentations, a worksheet on bacterial diseases was completed, and students individually engaged in reading and answering questions on an article about the benefits and risks of genetically engineered bacteria. Students also completed an intensive discovery-based lab in which they cultured and counted bacteria colonies and then prepared gram stained bacterial slides, included as Appendix C. Students worked cooperatively on the lab activity, but it was submitted individually. None of the learning activities or the labs strategically incorporated any of the NGSS practices. At the conclusion of the nonintervention unit, students completed the postunit target assessment, included as Appendix D, and then completed the preintervention student concept survey, included as Appendix E.

During our semester exam review day, students completed the preintervention biology engagement/motivational questionnaire, included as Appendix F, to help me assess their initial attitude and motivation towards biology prior to beginning the intervention portion of the project. Following the completion of their semester exams, students completed a preintervention survey regarding the instructor's care for students, included as Appendix G, to help me assess their initial perception of how much I care about them personally prior to beginning the intervention portion of the project.

The intervention units that followed used randomly assigned discussion groups organized by desk placements in groups of three that changed weekly. Each intervention unit began with a current article from *Science World* magazine or a lesson incorporating a recent video or news clip chosen to inspire interest and help students begin to see the relevance of the chosen topic. This initial activity was followed with a short PowerPoint presentation or student-activity related to this introductory material. Students had an opportunity to discuss the material within their groups and ask questions, as well as complete questionnaires or worksheets related to the material. After completing this introduction, they completed the appropriate preunit target assessment to help me determine their background knowledge of the topic.

The first intervention unit covered the molecular basis of genetics and took five full weeks. The introductory lesson began with students working in their discussion groups to read and discuss the article *One Ugly Pooch* from *Science World* magazine (2012). Students were given time to work together to create a color picture on the front of a birthday card that summarized the main idea of the article, and on the inside of the card explain why they would present this card to someone as a birthday gift. The article discusses how the Chinese Crested dog is a hairless breed of dog that has been developed through careful selective breeding. After completing their card, students had a short opportunity to ask questions and discuss the article as a class. The following day, students viewed a short PowerPoint presentation, which compared some of the results of selective breeding with some of the results of genetic engineering; breeds of dogs, cattle, and tomatoes vs. glow-in-the-dark fish, rabbits, and cats, featherless chickens, and hairless mice. Throughout the PowerPoint presentation students were encouraged to ask questions or discuss the various slides. After completing the presentation, students once again worked in their groups to collectively complete a short questionnaire, included as Appendix H, on the benefits and dangers of selective breeding and genetic engineering. In the questionnaire students were asked to provide evidence from the articles or presentation to support each of their answers. Once the questionnaire was completed, students engaged in a classroom discussion on the benefits and dangers of selective breeding and genetic engineering which was used to introduce students to the practice of engaging in argument from evidence. This required students to support their assertions on benefits or risks with evidence from the article on genetically engineered bacteria, the article on the Chinese Crested dog, or from the PowerPoint presentation, not their personal feelings. Engaging students in supporting claims with evidence and reasoning is a necessary step in moving toward effective use of scientific argumentation. Their homework assignment was to individually complete another questionnaire, included as Appendix I, on their personal thoughts and opinions regarding both selective breeding and genetic engineering. They again were required to support their thoughts or opinions with evidence.

Following this introductory lesson, students were asked to work together as a class to design the first in a series of three models. This model and its accompanying text illustrated and described how DNA is involved in determining hereditary. Creating this *before* model actively engaged students in the practice of developing and using models and allowed students to create a physical representation of their current shared understanding of how this process occurs. It also allowed the students and me to establish and agree on the drawing conventions that would be using with these models. Students then used this model to answer the five open-ended questions included on the preunit target assessment, included as Appendix J. Once the models and questions had been completed, the students and I worked cooperatively to generate a list of "gotta-have" explanations that the students felt were important to the final explanation. This list and student models provided a guideline for me of key elements or concepts of heredity that students were missing and served to guide the instruction for the unit. This list was modified every few days throughout the unit as new lessons related to heredity were completed. Creating this list provided students with a physical representation of their thinking, and modifying it every few days to include new ideas or relationships engaged them in supporting and challenging claims based on evidence. I used a combination of behaviorist and inquiry learning activities based on the gaps in student understanding indicated in the model to cover missing key concepts in asexual and sexual reproduction, the molecular composition of DNA, and the process of replication. Students actively engaged again in the practice of developing and using models by using Carolina Biological's DNA Structure and Function Kit (2004) and their manipulative models to complete the activity, which focused on solidifying their understanding of the molecular composition of DNA and the process of DNA replication. They then answered some questions I developed related to the activity, included as Appendix K. Students used the physical manipulative model to create nucleotides, connect nucleotides in a prescribed order to create a double-stranded sequence of DNA and then unzipped the DNA strands and connected free-floating nucleotides to mimic the process of replication. Building and manipulating these physical models provided students the opportunity to conceptualize and visualize processes which they cannot see.

Throughout the entire unit, at the end of each week students were required to use the practice of engaging in argument from evidence to cooperatively create a summary table consisting of four columns showing the various activities completed in the unit. The four columns included on the table were labeled: Activity (activities completed), Observations (patterns or observations made based on the activity), Why (what the activity revealed about how DNA is involved in determining heredity), and Clues (how the activities helped us modify our thinking about how DNA is involved in determining heredity).

At the end of each weeks lessons, students were also asked to spend 15 to 20 minutes reviewing their initial model of how DNA is involved in determining heredity, and to add comments to the models, initially their own and then later in the unit, those of their classmates using color-coded sticky notes. The comments were organized into three categories: orange sticky notes were used for those suggesting the “addition of an idea”, green was used for comments suggesting the “revision of an idea”, and purple were used for comments which “posed a question” regarding the model. These comments required the inclusion of evidence drawn from the summary table and had to follow a specific format outlined in Appendix L. Once the comments were made, we engaged in arguing from evidence to cooperatively update our “gotta-have” checklist for the models, allowing students to modify and strengthen their consensus explanation.

Once this portion of the unit was completed, students were asked to review the comments on their model. Using both the comments and the new scientific ideas they had learned and the experiences they had, cooperatively with their discussion group, students engaged yet again in the practice of developing and using models by creating a new model with text. They were required to incorporate new evidence in their understanding of how DNA is involved in determining heredity. After the *during* model was completed, I again used a combination of behaviorist and inquiry learning activities based on the gaps shown in student understanding indicated by these new models to cover missing key concepts in transcription, translation, protein synthesis, and meiosis. Again during this portion of the unit, students were asked weekly to engage in arguing from evidence to add comments to the models using the color-coded sticky notes and evidence from the summary table and to continue developing the “gotta-have” checklist. An additional activity, which allowed students to connect DNA sequences with proteins affecting visible phenotypic traits, was added to the unit at the last minute in an effort to help students make final connections between genes, proteins, and visible phenotypic traits.

At the conclusion of the unit, students were asked to individually complete an explanatory model with text that illustrated and described how DNA is involved in determining heredity incorporating the comments and the new material that they learned throughout the unit, and compare this *after* model to the original group consensus *before model*. This provided them an opportunity to see how their understanding of this concept had changed throughout the course of the unit and to become more aware of their thinking process. In completing their final explanatory model, they were required to access the “gotta-have” checklist as well as to use at least two of the columns from the summary table. They then used their model as evidence in answering the 5 open-ended questions included on the postunit target assessment, included as Appendix M. This *before-during-after* modeling activity was designed based on *The Modeling Toolkit* by Windschitl and Thompson (2013). At the conclusion of the unit, students also completed the postunit concept survey, and the postintervention engagement/motivational questionnaire to help me assess changes in their attitude and motivation towards biology. I compared scores between the pre and postunit target assessments.

The second intervention unit covered genetic principles and took four full weeks. To introduce the unit, I gave a brief PowerPoint introduction to Gregor Mendel and his work, which included a short video presentation on what a gene is. The following day, students completed an in depth inquiry lab on mathematical probability using 10-sided dice and pennies, which also incorporated an introduction to the mechanics of gene inheritance, included as Appendix N. After completing the lab, students were asked to answer 5 open-ended questions as a preunit target assessment, included as Appendix O. Following completion of the preunit target assessment, the students and I engaged in arguing from evidence to cooperatively generate a list of “gotta-have” procedures that the students and I felt were essential to include in using the Punnett square model to support the conclusions. The model and the “gotta-have” procedures became key tools for students to use in engaging in the practices of developing and using models and using mathematics and computational thinking to solve problems related to Mendelian genetics. Students then engaged in the practices of using the model as well as using mathematics and computational thinking to learn to solve monohybrid cross practice problems, a number of test cross, incomplete and codominance cross practice problems, as well as practice problems involving dihybrid crosses. These activities allowed them to use the model to engage in both visualizing and explaining how the principles of genetics apply to real organisms.

Throughout this period, students were given challenge problems every other day that they were required to work cooperatively to solve. An example challenge problem is included as Appendix P. Groups were then both randomly and selectively chosen to present and use the practice of engaging in argumentation to support their solutions to the rest of the class. This provided the opportunity for them to engage in agreeing and disagreeing with peers and allowed them to begin questioning other people's claims. This practice is necessary for them to begin to understand how this practice actually works in the scientific community.

The final challenge problem of the unit, included as Appendix Q, provided students with a scenario in which one rancher (the plaintiff) claimed another (the defendant) had cut a fence to allow the plaintiff's bull to bred with the defendant's cows. The defendant claims he used sperm from a well-known sperm bank to artificially inseminate (A. I.) his cows. Individual students were assigned the task of representing each of the respective ranchers and an arbitrator, and the remaining students were divided into the prosecuting and defense team attorneys. Each "rancher" was provided a background sheet of information they could provide to their team. Teams were given two class periods and access to the internet to research and prepare their case. Each team was then required to use evidence to effectively argue their claim before the arbitrator in 15 minutes and the opposing team was given 5 minutes to provide a rebuttal to the claim. The following day, the arbitrator was required to render a decision regarding the initial claim and provide their evidentiary reasoning for the verdict. Following the conclusion of the case, we discussed cases of "bad science" or misinterpretation within each teams' evidence and students completed the postunit engagement/motivational questionnaire. The activity was designed using the concepts presented by Clary and Wandersee (2013). Students then completed the postunit target assessment, included as Appendix R.

At the conclusion of the unit, students again completed the postunit concept survey, and the postintervention engagement/motivational questionnaire to help me assess changes in their attitude and motivation towards biology. I compared scores between the pre and postunit target assessments.

I believed that by incorporating the NGSS practices of developing and using models, using mathematics and computational thinking, and engaging in argument from evidence into my units I would arouse the students' interest, increase their perceived relevance of the task, and provide them with opportunities for success. If I effectively increased engagement and motivation, student understanding of biological concepts should increase as well.

Data Collection Instruments

Sheridan High School is a public high school that services Sheridan, the county seat of just over 17,000 people and a surrounding rural community of just over 29,000 in northeastern Wyoming. The largest employer in the community is the school district, followed by the community hospital, and the veteran's hospital. Many residents are actually employed across the state line in Montana by a couple of large coal mines and small scale farms and ranches are prevalent in the surrounding community. Sheridan High School serves approximately 920 students over four grade levels, with 89% of students identified as Caucasian, 5% Hispanic, 4% Asian, and 2% other (American Indian, Black, and Pacific Islander). Approximately 29% of the student body is identified as being at risk of failing to graduate. I teach a total of 5 classes on three different subjects related to the biological sciences, with an average of 100 students. Sheridan High School has a separate accelerated program for higher achieving science students.

The students who initially participated in the intervention were the members of my general biology course, consisting of one freshman, 16 sophomores, two juniors, and one senior, 11 of which were male and 9 female. By the conclusion of the study, one of the female sophomores had moved, one of the male sophomores had transferred to another class and another male sophomore replaced him, and one of the juniors and the senior had dropped out. This reduced the number of students participating in the intervention to a total of seventeen. Class time was from 10:14 AM to 11:06 AM. Only about half of these students indicated any desire or intention of pursuing college after high school, although several indicated a desire to attend some type of trade school. All of the students were Caucasian and the majority were in the middle to upper socioeconomic level. Approximately 30% of the students were identified as being at risk of failing to graduate, and had had difficulty with science courses in the past. Most students within that 30% had a generally poor attitude and little motivation towards science and school in general. Reading levels of the students ranged from 4th to 12th grade. None of the students were enrolled in special education, and only one student had an individual learning plan (ILPs). Several of the students in the course have been in some type of trouble with law enforcement and were on probation and about half the students were from group or single parent homes rather than traditional families.

The triangulation matrix, shown in Table 1, summarizes the three sources of data that were used for each of my questions, using multiple sources allowed me to triangulate my data. Triangulation of the data was conducted to provide a more accurate representation of the effects of the intervention and reduced the likelihood of misinterpreting a single source. Comparisons were made between data collected from both the nonintervention and the intervention units.

Table 1
Data Triangulation Matrix

Project Questions	Data Source 1	2	3
Effects on students' understanding of biological concepts	Pre and postunit capstone project target assessments (with each unit)	Pre and postunit student concept interviews	Pre and postintervention student concept surveys on their perception of understanding
Effects on students' engagement and motivation towards biology	Instructor field notes	Pre and postintervention nonconcept interviews	Pre and postintervention biology engagement/motivational questionnaire with student quotes
Effects on my teaching and motivation as a science instructor	Instructor field notes with prompts	Pre and postintervention instructor surveys	Nonintervention and intervention observations by colleague
Effects on students' perception of instructor caring	Instructor field notes and reflective journal with prompts (nonintervention and intervention units)	Pre and postintervention survey regarding instructor’s care for students	Student quotes (pre and postintervention surveys) and nonintervention and intervention observations by colleague as well as instructor field notes and instructor reflective journal

To determine the effect that developing and using models, using mathematics and computational thinking, and engaging in argument from evidence had on students' understanding of biological concepts, data were collected using pre and postunit target assessments, pre and postunit student concept interviews, and pre and postintervention student concept surveys.

The use of pre and postunit target assessments at the beginning and end of each unit allowed for a comparison of percent change in student understanding. These assessments, each of which described a real world scenario appropriate to the key concepts of each unit, contained five open-ended questions created using successive levels of Bloom's taxonomy to evaluate percent change in students' understanding of the concepts.

Pre and postunit student concept interviews, included as Appendix R, conducted outside of regular class time required students to probe their own feelings about their comprehension of the course material and how using models, mathematics, and scientific argumentation helped them achieve a more comprehensive understanding of the materials. For the interviews, I selected six students that I felt would be open and honest as well as forthcoming with valid and helpful responses. I chose two students who demonstrated high motivation and previously were highly successful in understanding biological concepts, two students who were generally motivated and successful in understanding biological concepts and two students who were typically unmotivated and unsuccessful in understanding biological concepts. I used the same 6 students for all the interviews I conducted. Students were asked to construct a concept map or model using terminologies provided, and use these tools to answer a single question written at the highest level of Bloom's taxonomy in essay form. These questions were designed to provide a comprehensive snapshot of student understanding due to their being inclusive of all prior levels of Bloom's. The concept map or model was evaluated using the concept map scoring rubric included as Appendix T and the response were evaluated using a rubrics adopted from the one developed by Peirce (2006).

Pre and postintervention student concept surveys were completed at the end of the nonintervention unit and again at the end of each of the intervention units. The questions on the survey employed a Likert scale to measure students' perception of their own understanding of the topic and additional open-ended questions on the survey helped to identify which activities students enjoyed, found the most helpful, and found to be the most frustrating.

The effects of incorporating the practices of developing and using models, using mathematics and computational thinking, and engaging in argument from evidence on student engagement and motivation were measured using instructor field note observations of student behaviors and engagement, pre and postintervention nonconcept interviews, and a pre and postintervention biology engagement/motivational questionnaire. The use of both student and instructor perception of engagement and motivation provided a more thorough representation of data and allowed for easy identification of outliers and aberrant data.

Throughout the study, I made observations and kept field notes regarding student motivation and engagement with the activities during class, using a Likert scale score of 1 to 5 to record how engaged and involved the students were with each day's lesson. I then used additional prompts to help me record my observations in my field notes, included as Appendix U, and did my best to record these observations either during or directly after class.

Pre and postintervention nonconcept interviews, included as Appendix V, were conducted at the completion of the first unit and the third to accurately gauge the change in student motivation and engagement brought about by incorporating the intervention. The first five questions remained the same throughout the entire project, and two additional questions were added for each of the intervention units.

The pre and postintervention biology engagement and motivational questionnaire was given to all students upon completion of each of the three units. The first six questions were designed to measure the students' perception of their own engagement and motivation and the remaining questions were to help me focus in on what students found enjoyable or frustrating about the class, as well as to gain some input on what they perceived as their own motivating factors. Measuring these after the nonintervention and each intervention unit allowed me to determine how the intervention impacted student attitudes and enthusiasm in each unit.

To determine how developing and using models, using mathematics and computational thinking, and engaging in argument from evidence impacted my own motivation as the course instructor, I used my field notes with prompts, instructor surveys (Appendix W), and observations by colleagues. The survey was completed following the nonintervention unit and after each of the intervention units to monitor the effect that teaching each of the intervention units had on my motivation, as each incorporated the intervention in slightly different ways. I was observed by my colleague and my Principle once during the nonintervention unit and once during each of the intervention units using the observation form included as Appendix X. These observations helped by providing an outsiders view of how using the different practices impacted my interactions with students as well as the classroom environment. I also incorporated some of my own observations from my field notes and my reflective journal.

My field notes and reflective journal with prompts (Appendix Y), a survey regarding instructor's care for students, student quotes from the pre and postintervention surveys, and observations by my colleague were also helpful in determining how using lessons that developed and used models, required using mathematics and computational thinking, and allowed students to engage in the practice of arguing from evidence impacted my ability to build relationships with students and students' perception of me as a caring instructor. My reflections recorded students' perceptions of students' perceptions of how I personally cared about them. I recorded my reflections once a week at the end of the week, using the prompts. The student surveys in particular gave me a first-hand look at students' perceptions of how much I cared for them as individuals, as well how much I cared about teaching the course itself.

Field notes, journaling, student comments on surveys, and personal interviews provided insight into individuals and how the intervention affected their personal engagement and understanding of the concepts, as well as providing information on why it may or may not have been successful for a particular student.

DATA AND ANALYSIS

Data from the nonintervention and intervention units were compared to determine the effects of incorporating the specified practices of NGSS on students' understanding of biological concepts, on students' engagement and motivation towards biology, on my teaching and motivation as a science instructor, and on students' perception of instructor caring. In each unit data were collected from multiple sources to allow for triangulation. Because participation was voluntary, *N* values on all of the data fluctuates as the general biology students were not motivated to volunteer time outside of the classroom to make up activities related to the study.

The use of pre and postunit target assessments enabled me to compare the percent change in student understanding between the three units. Data from the analysis of the pre and postunit assessments can be found in Table 2. The results show a greater gain in conceptual knowledge for the intervention units vs. the nonintervention unit as reflected by the percent change, particularly in the second intervention unit.

Table 2
Percentage Change in Assessment Average (Range) in Three Units

Description of Data	Nonintervention (%) (*N* = 12)	Intervention 1 (%) (*N* = 12)	Intervention 2 (%) (*N* = 15)
Preassessment Average	27 (0-70)	43 (0-100)	36 (0-80)
Postassessment Average	30 (10-70)	60 (30-80)	81 (30-90)
Percent Change	11	40	125

Data were also collected to determine the change in understanding of biological concepts through interviews which combined survey questions of student perception of their skills as well as concept maps and conceptual questions. These findings were broken down in terms of low, middle, and high-achieving students and can be found in Figure 1.

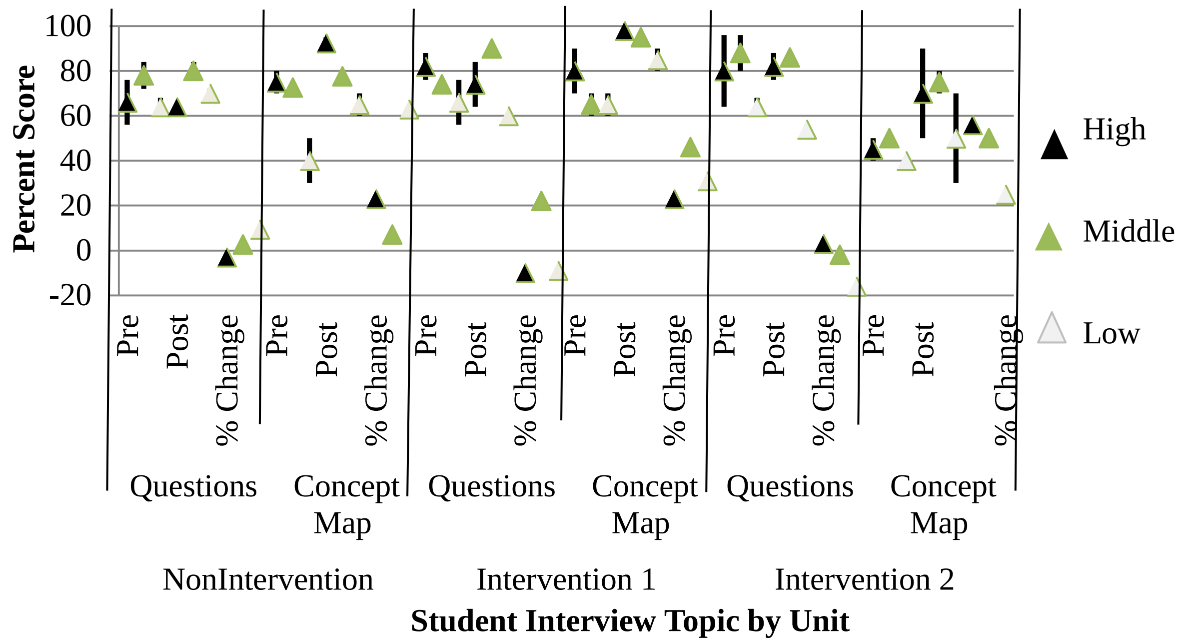
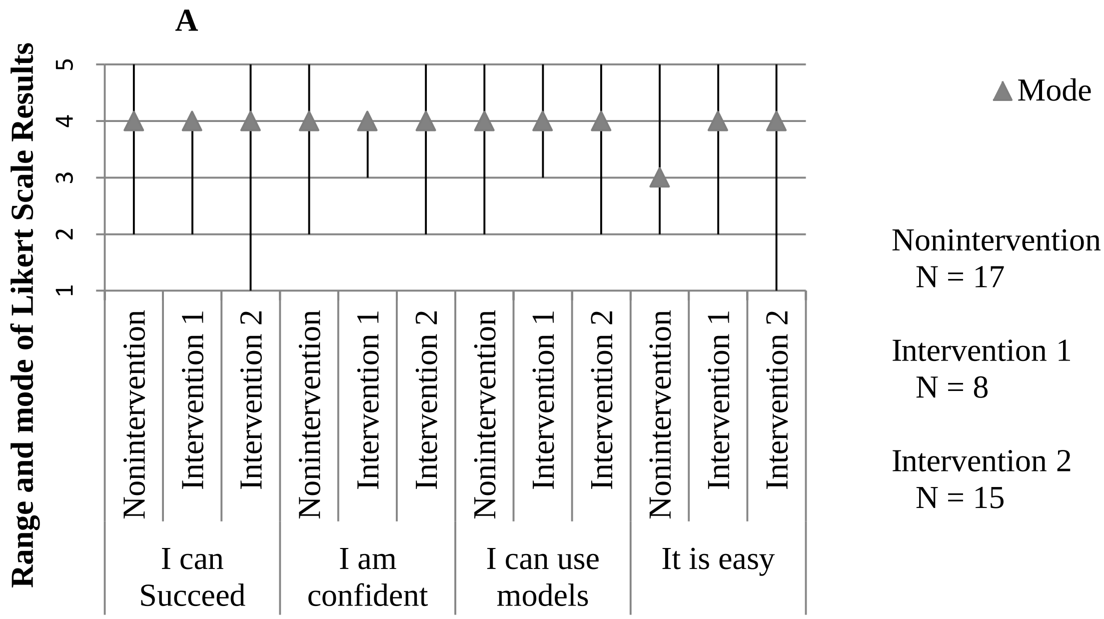


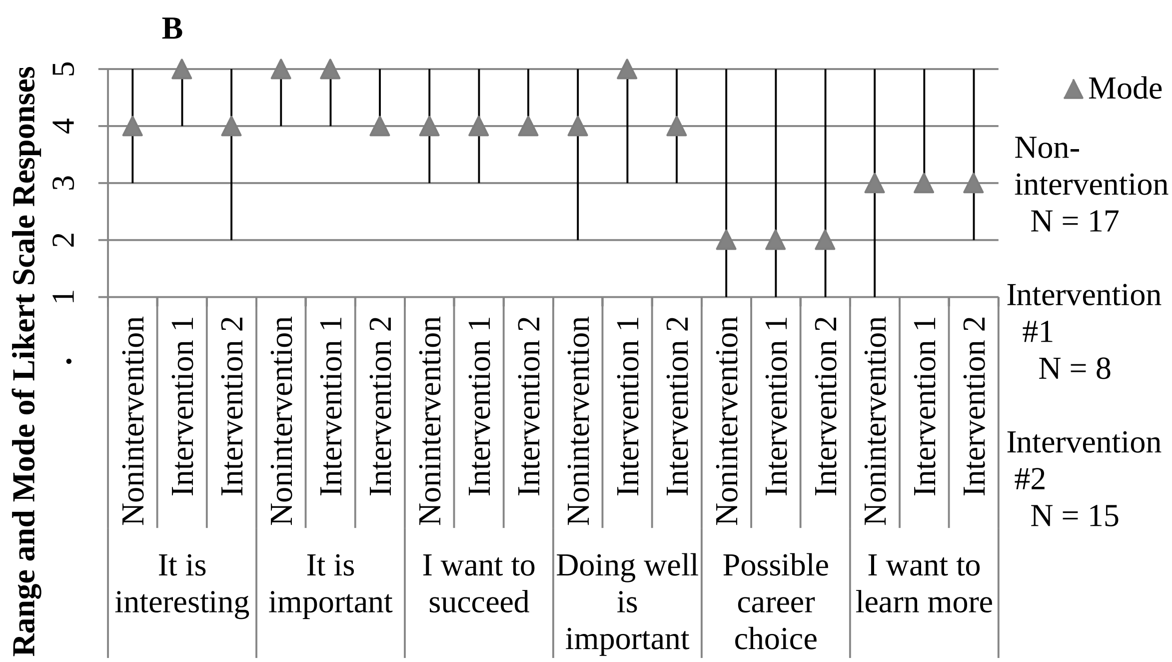
Figure 1. Average student responses showing range (indicated by bars) and percent change in nonintervention and intervention concept interviews on concept mapping and survey questions regarding their understanding of biological concepts, (*N* = 6).

Students responded to the interview questions using a Likert scale with responses of not at all, very little, somewhat, generally, and lots. The concept maps were scored using the concept map scoring rubric and the student responses were also evaluated using a rubric. The data shows some interesting trends. The preunit interview survey questions in the intervention units showed students perception of their understanding to be average to high, while their perception of their understanding of the nonintervention unit was low to average. I attribute this to the fact that students have had exposure to both molecular and Mendelian genetics in eighth grade, but their previous exposure to bacteria was more limited, consisting of only a brief introduction during the ecology unit. Their preunit interview concept maps and understanding of conceptual questions showed their actual understanding to be low to average in all units; while they recognized basic vocabulary and made connections, they included few new vocabulary terms and made limited to no cross-connections. Following their exposure to the two intervention units, students' perception of their understanding of the concepts dropped, particularly among the low students, but during intervention #2 it also dropped amongst the average students. During the interview process, one low-level student commented, "I'm confident that I can do it, but I'm just not good at it." One of the higher level students commented, "I can't make them very well, but if I have them, I can explain them." I attribute this again to their exposure to molecular and Mendelian genetics in eighth grade, which was on a very general level with easy, fun and exciting activities. They arrive at the high school believing they know everything about these topics, and quickly learn as we delve into the detail and the specifics that the topics are much more difficult than they previously believed. Their postunit interview concept map scores, however, showed improvement in conceptual understanding across the board. The increase in average scores of concept mapping and conceptual questions clearly shows a gain in their understanding and ability to communicate that knowledge; they made more cross connections and included new vocabulary. Their perception of their understanding of that information decreases, particularly among low achieving students.

Additionally, data were collected on students' perceptions of their own understanding using concept surveys following each of the nonintervetion and intervention units. This 17 question survey was given at the completion of each unit. The 13 subjective questions were not scored for a grade, but used a Likert scale with answers of strongly disagree, disagree, unsure, agree, and strongly agree. The results are divided into three general areas; how I feel about myself, how I feel about the subject and how I feel about the learning activities, and are summarized in Figure 2 below.



Survey Questions Regarding Student Self Reflection: How I Feel About Myself



Survey Questions Regarding Subject Reflection: How I Feel About The Subject

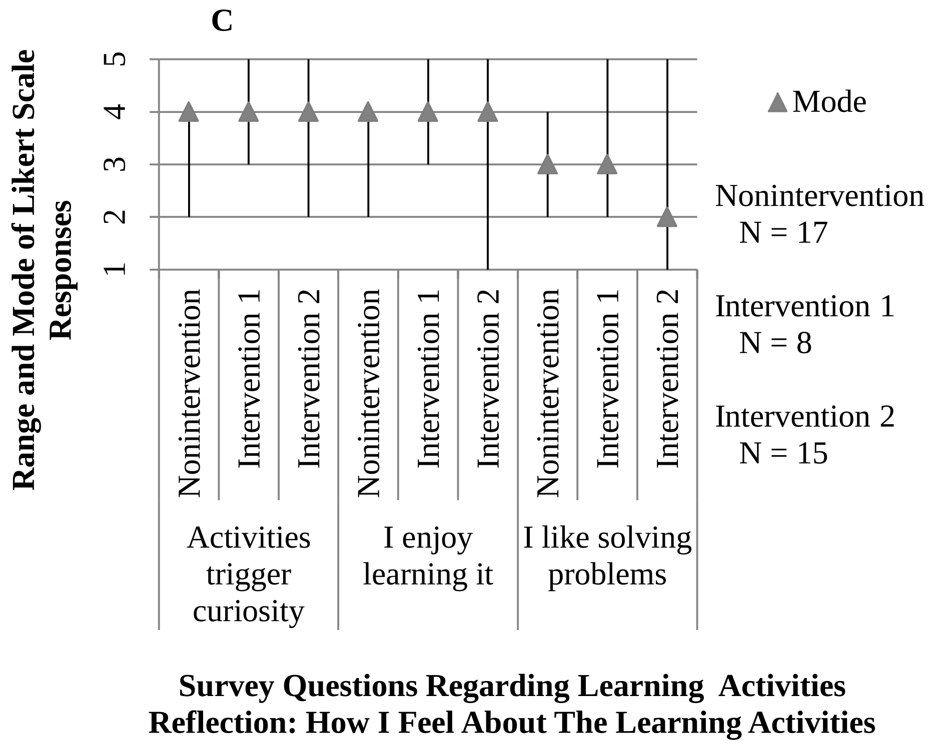


Figure 2. Likert scale range (bars) and mode (▲) of student responses to survey questions on student perception of concept understanding of biological concepts. *Note* Likert scale 5 = strongly agree and 1 = strongly disagree, *Figure 2A* = how I feel about myself, *Figure 3B* = how I feel about the subject and *Figure 3C* = how I feel about the learning activities.

It should be pointed out that the limited number of responses to the survey for intervention #1 could create a biased response.

Four additional open-ended questions on the survey provided further insights into student perceptions of their understanding. When asked what additional areas related to bacteria they would like to explore further, student responses ranged from “none” to “everything”, and included “the role they play in baking”, “the parasitic role of bacteria” and “diseases and illness.” When asked what activities related to bacteria frustrated them the most, student responses ranged from “I don’t know” to “there were none and all the activities helped.” When asked what additional areas related to molecular genetics they would like to explore further, responses included “none”, “genetics of our own families ☺”, and “DNA structure and the various chemicals that work together to form the structure.” In regards to what frustrated them, student responses included “none ☺”, “decoding RNA to proteins”, and “replication labs and models.” On the genetics survey one student indicated that they had no interest in pursuing additional areas related to genetics because “it’s complicated,” and another indicated that they “hate this class.” Over 53% of students indicated that they most enjoyed the arbitration challenge problem out of all the genetics activities. Not surprisingly, different students learned best from and were frustrated by, different parts. One student indicated that the class activity that helped them learn the material the best was “the meiosis activity on the computer”, while another student gave the same response when asked what activity frustrated them the most related to the topic. It was not uncommon that the activity that one student indicated they learned the best from was often the activity which another student found the most frustrating.

Initially it appears that the survey data contradicts the interview data; the interview data appears to show that overall student confidence in their understanding of the biological concepts and their ability to use the NGSS practices increased slightly in all areas. However, the interview data also shows that students’ average interests in continuing to learn about these activities decreased. Interestingly the mode of student responses to the question related to the importance of the topic was five for the nonintervention and intervention #1, but decreased to four for intervention #2. In reviewing the survey data, it appears that students assigned more importance to bacteria and molecular genetics than to principles of genetics. Twelve out of seventeen students strongly agreed that bacteria is important, five out of eight strongly agreed that molecular genetics is important, while only two out of fifteen strongly agreed that genetic principles were important. When asked what areas related to bacteria they would like to explore further, the majority of open-ended responses on the bacteria unit related to human disease. It is also interesting to note that students most often indicated they were unsure if the nonintervention was easy, but most often agreed that intervention #1 and intervention #2 were easy despite the addition of the NGSS practices, even though in their explanations they indicated they were not good at math.

The data suggests that after implementation of the NGSS practices, students did show an increase in their understanding of biological concepts, even though their perception was that they understood less. Discussions with students during the interviews revealed that while they understood the basics initially, they lacked real understanding of how DNA and Mendelian genetics worked, but by developing and using models, using mathematics and computational thinking, and engaging in argument from evidence they were able to broaden their understanding, while realizing that there is a lot more to learn.

To study the effects of incorporating the indicated NGSS practices on students' motivation and engagement, I tabulated observations in my field notes consisting of a daily number recording my observation of each student's engagement during the nonintervention and both intervention units. I took the median of the results of all students to get a general sense of overall student engagement and motivation on a daily basis. Results are show in Figure 3 below.

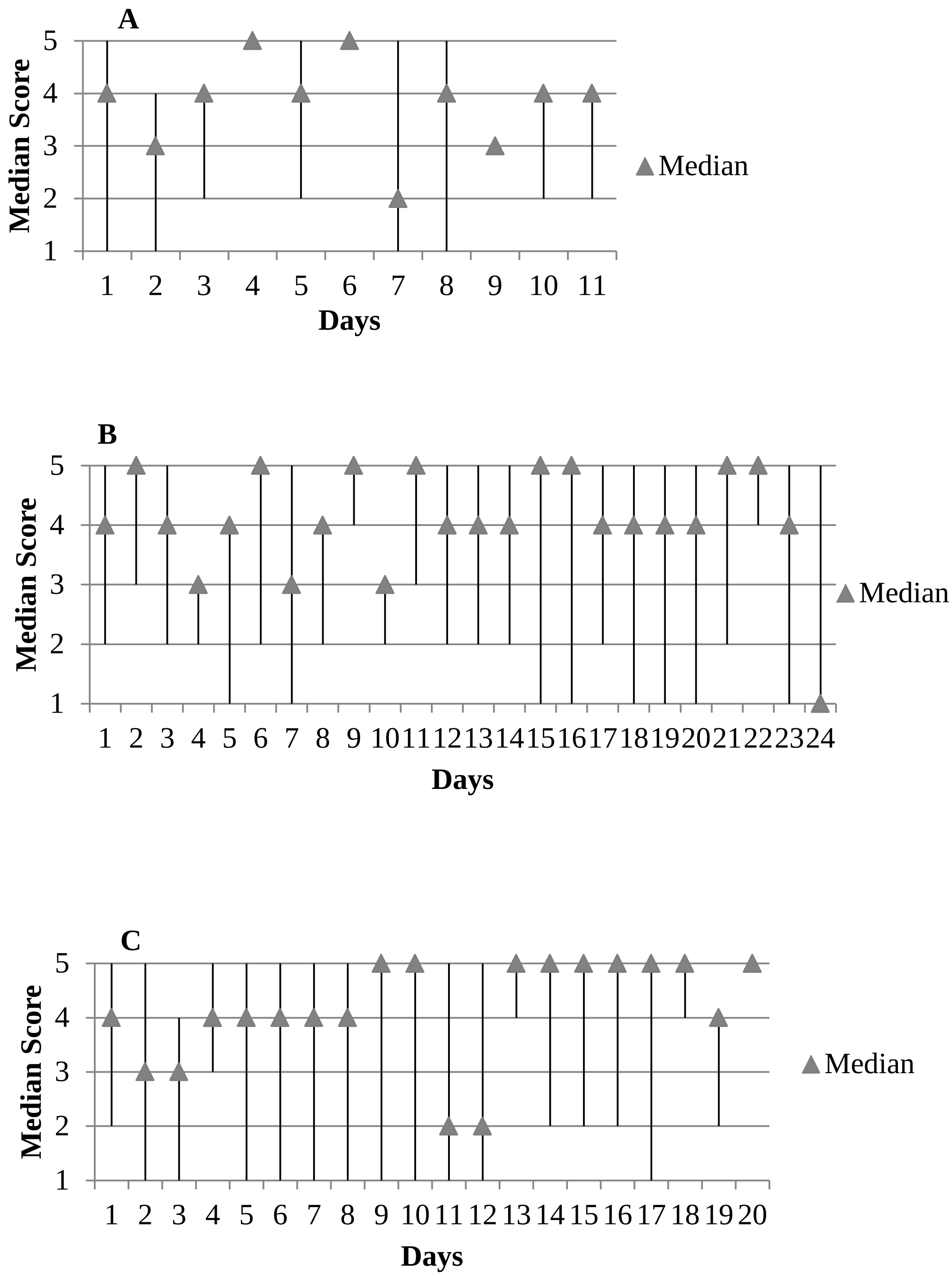


Figure 3. Median score and distribution (bar) for daily student engagement/motivation by unit. *Note* 1 = little to no engagement and 5 = fully engaged. *Note Figure 3A* = nonintervention, *Figure 3B* = intervention #1 and *Figure 3C* = intervention #2 (*N* varied daily based on attendance).

It should be noted that both the major dips in the data of both the nonintervention and intervention #1 represent review/postassessment days. Figure 3A shows inconsistent student engagement and motivation throughout the nonintervention unit, Figure 3B shows inconsistently high engagement and motivation throughout intervention #1, and Figure 3C shows high engagement and motivation that increased towards the end of intervention #2. Reviewing my field notes reveals that the drops in engagement in the nonintervention unit are tied to student activities vs. traditional teacher centered activities consisting of lecture and worksheets. Drops in engagement in intervention #1 are tied to assessments or students engaging in creating models of their understanding. I attribute these drops in engagement to the difficulty of the assessments, both pre and post, which I used, and the fact that students have previously had very little exposure to creating models on their own. The two day dip in the data in intervention #2 correlates to students learning how to do dihybrid crosses. I attribute this to the fact that many students disengaged and gave up trying to figure out how to do these and never completed the assignment. The following rise in student engagement during intervention #2 correlates to beginning the mock arbitration case. I attribute this to the fact that students were able to identify the application of what they had learned regarding genetic principles to a real life situation with which they could identify and thus they increased their engagement.

Additionally, I conducted pre and postintervention nonconcept interviews. The preintervention nonconcept interviews consisted of five open-ended questions mainly regarding learning activities. The postintervention nonconcept interviews asked the same five questions and added two questions regarding the use of math, designing models, and providing supporting evidence. During the preintervention interviews 98% of students interviewed indicated that hands-on lab type activities allowed them to understand the material the best, however that number dropped to 28% in the postintervention interviews. I attribute this to the fact that the NGSS practices for genetics involved more practice problems and challenge questions than hands-on type activities. 50% of students in the postintervention indicated that the practice problems completed during class were most helpful in helping them understand the material, and 14% indicated that the arbitration case was most helpful. Analyses of example activities provided to the question "What was your favorite activity in this unit? Why" revealed that 96% of students in the preintervention preferred hands-on activities which were graded primarily on participation rather than concept understanding. This number dropped to 85% during the postintervention. The primary reason provided for enjoying these activities, "it was fun." One student did state that the arbitration case "was a fun activity that aided in understanding" and another said, "the mock trial because it helped me understand genes a little better and find out what real evidence is in a fun way." During the postintervention nonconcept interviews 64% of students indicated that they enjoyed using math, designing models, and providing supporting evidence. One student stated, "the Punnett squares were engaging and informative," and another said, "it helped me understand better with like math cause I'm good at it and models help you visualize it." Asked if they think using math, designing models, and providing supporting evidence affects their higher order thinking skills, 93% of students responded affirmatively, and when asked to provide examples one stated, "Yes because the activities required the research and evidence gathering to support answers to the best of our ability." Another stated, "Yes, it makes you put effort into it and think about it."

Overall, the data indicated that incorporation of the NGSS activities was successful in increasing student engagement and motivation.

For the final data set for studying the effects of incorporating the indicated NGSS practices on student's motivation and engagement I administered a pre and postintervention engagement/motivational questionnaire. The initial six questions used a Likert scale, while the remaining five questions were all short answer. Question #10 was changed for the pre and postintervention questionnaires. I analyzed the data from the first six questions for both range and mode; results are shown in Figure 4 below.

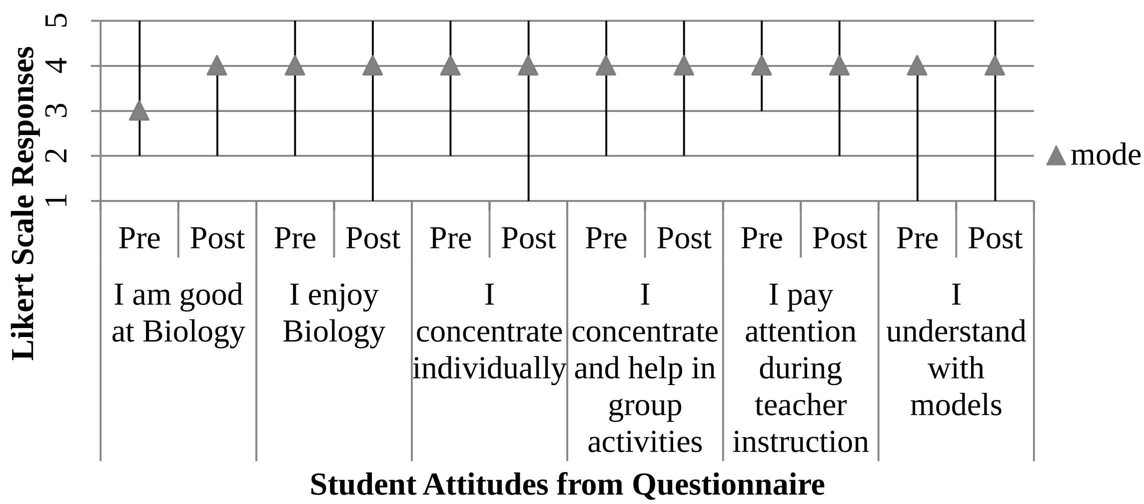


Figure 4. Likert scale range and mode results of student responses to biology pre and postintervention engagement/motivational questionnaire. *Note* 1 = strongly disagree and 5 = strongly agree (*N* preintervention = 13, *N* postintervention = 15).

The mode increased a whole point in students' responses regarding whether they think they are good at biology between the nonintervention and postintervention questionnaires. For the other questions, the mode remained at 4 for both pre and postintervention questionnaires, but for five of the questions the overall range of responses appeared to increase. I attribute some of this to the fact that for the preintervention questionnaire only 13 students responded and one student left the entire back of the questionnaire blank, making it likely that the nonmotivated students never bothered to complete or turn in the questionnaire, thus reducting the range of the preintervention questionnaire. For the postintervention, I collected a completed questionnaire from every student and my general impression is that students appeared to be more honest with their answers, as they fit closely with my own observations.

Initially my observations of student engagement and the Likert scale responses of the students on the Questionnaire appear to be at odds; I attribute that to student perception of being engaged vs. adult perception of being engaged. Reviewing student written responses helped to reconcile these apparent differences. One student who indicated that she agreed that she was engaged wrote, “people usually end up talking and I get distracted during class, but I usually finish my work at home,” another who also indicated she was engaged wrote “I love biology, but if I don’t understand then I don’t pay attention at all.” Reviewing student’s answers to the short answer questions also helped to understand the apparent discrepancy. Asked what they enjoyed about biology, one student wrote “I try to like science but I can’t understand it,” another wrote “I just like it when I can answer questions and understand things, it makes me feel smart.” Asked if using mathematics, models and/or supporting evidence motivated and/or engaged you in studying biology, the same students responded “yes, but I just get lazy and only do stuff half way,” another replied, “yes, because it made me come up with my own evidence and facts.” Asked in the preintervention what motivates them to learn new concepts in biology, 46% responded with “grades or credit.” Asked in the postintervention what was the biggest change they noticed in their own attitude or motivation towards biology after learning to use math, models, and supporting evidence 73% indicated increased motivation and enjoyment. One student wrote, “biology is still hard, but I also think it is fun,” and another replied with, “there was an increased understanding and acceptance of the role biology has on day to day life.”

Findings from student responses to both nonconcept interviews and the questionnaire reinforced my observations that incorporating the NGSS practices facilitated the motivation and engagement of the students. One student summarized this well with his response, “the mock trial showed real life application to genetics and encourages you to actually look things up.”

To analyze the effects of incorporating the indicated NGSS practices on my teaching and motivation as a science instructor, I reviewed data from my pre and postintervention field notes, pre and postintervention instructor surveys, and pre and postintervention colleague observations.

In my field notes, I indicated both my daily attitude and motivation using a Likert scale, with 1 indicating little to no engagement on my part and 5 indicating that I was fully engaged. Results for the Likert scale portion are recorded below in Figure 5.

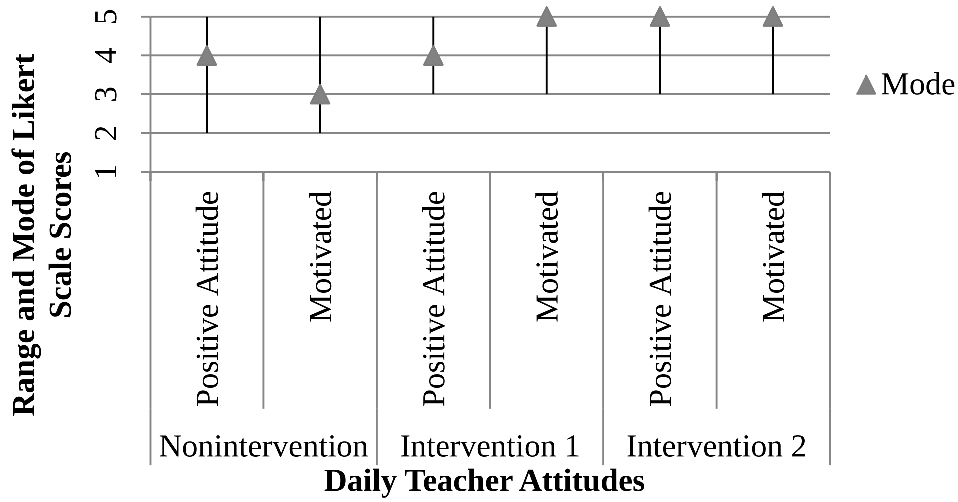


Figure 5. Likert scale range and mode results of instructor responses to biology pre and postintervention daily field notes attitude/motivational question prompts. *Note* 1 = strongly disagree and 5 = strongly agree (*N* = 1).

Figure 5 shows a clear increase in motivation from nonintervention to the intervention units and a consistent attitude followed by an improved attitude for the final intervention unit.

To study the effects of incorporating the indicated NGSS practices on instructor motivation and engagement, I tabulated observations in my field notes consisting of a daily number recording my observation of my own engagement during the nonintervention and both intervention units. Results are show in Figure 6.

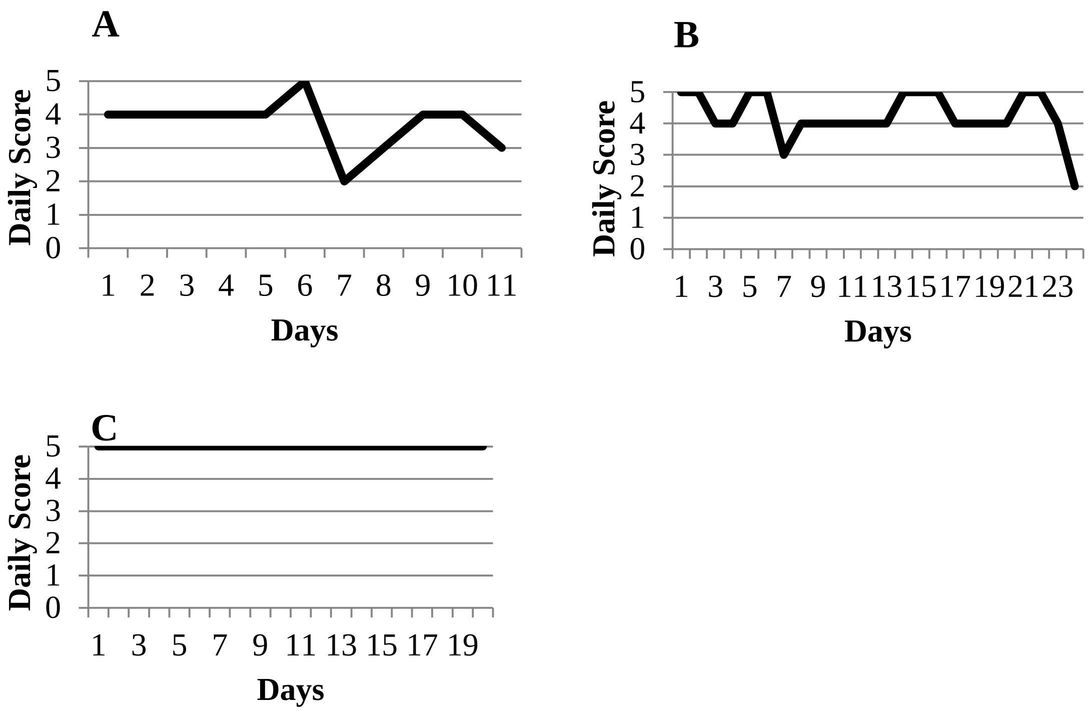


Figure 6. Daily instructor engagement and motivation by unit. *Note* 1 = little to no engagement and 5 = fully engaged, *Figure 6A* = nonintervention, *Figure 6B* = intervention #1 and *Figure 6C* = intervention #2.

Here again, the dips in Figures 6A and 6B for the nonintervention and intervention unit #1correlate with review/postassessment days. I attribute this to the fact that I scored myself as less engaged because the students were doing the work and I was not. While I also completed a postassessment for intervention #2, due to issues with the assessment itself, I was highly engaged in making adjustments in order for students to complete the assessments. Overall the data shows inconsistent engagement/motivation during the nonintervention unit, inconsistent but higher engagement and motivation during intervention #1 and consistently high engagement during intervention #2. While in part these results are due to my engagement/motivation in regards to changing instruction, it is also due in part to the fact that I simply enjoy teaching principles of genetics more than I enjoy bacteria and molecular genetics.

Data from the pre and postintervention instructor surveys were collected and analyzed in Figure 7 below. The first six questions employed a Likert scale rating with explanations and questions seven and eight were open-ended short answers questions.

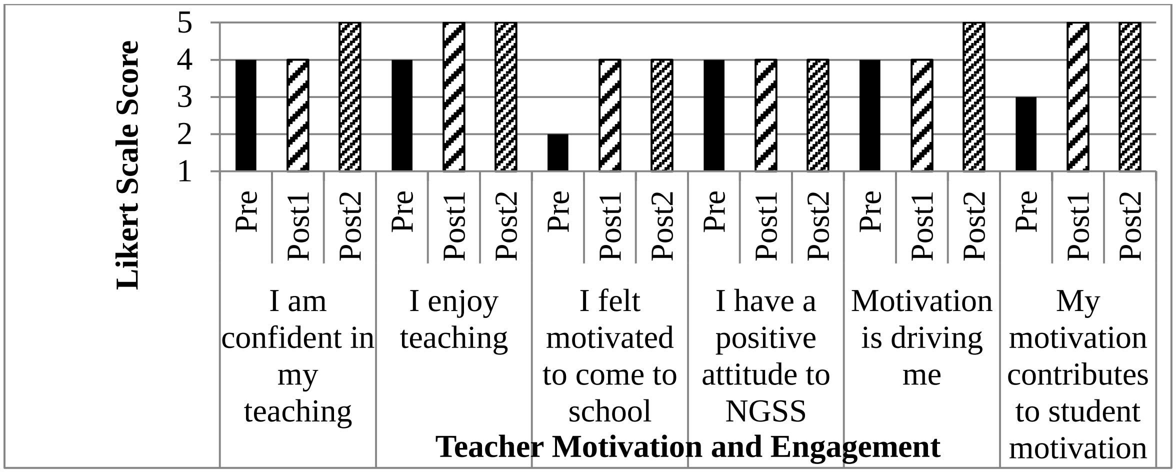


Figure 7. Likert scale results of instructor responses to pre and postintervention instructor engagement/motivation survey. *Note* 1 = strongly disagree and 5 = strongly agree, (*N* = 1).

The data shows an increase in my perception of enjoying teaching, my motivation to come to school, and my perception that my motivation contributes to student motivation. My perception of confidence in my teaching and that motivation is driving me did not increase until treatment #2. I attribute that to the fact that I also have had little formal training in having students create models of their understanding and I was apprehensive of the results. In my explanation to question #5 for the preintervention survey I wrote, “I’m always trying new methods and new things, looking to add to my toolkit,” for the postintervention #1 survey I wrote, “use of new practices is always challenging and sometimes difficult, but it forces growth,” and for postintervention survey #2 I wrote, “success breeds success, if I can engage them, I can eventually motivate them.” My attitude toward the selected practices of NGSS remained unchanged through all three units, and I attribute this to the fact that I have seen the value in these three practices in the biology classroom from the beginning and was looking forward to their implementation. In response to question #7, what is my motivation to teach, I wrote “to impart scientific knowledge and skills to students. I have trouble motivating students who have no desire to learn, and with this generation of students that can be very tough” for the preintervention survey. For postintervention survey #1 I wrote, “to impart scientific knowledge and skills to students, by allowing students to see me attempting to adjust my methodology, motivated several of my students to step up their game,” for postintervention survey #2 I wrote, “to engage students in learning science and scientific skills, working to engage all students pays off, but can be difficult” While the change in motivation is subtle, it is quite clear. I’ve moved from trying to “teach” students to “working to engage students.” In response to question #8, what is contributing to my attitude toward teaching, my attitude changed from, “students who have no desire or motivation to learn coupled with government policies which end up forcing schools to pass students because they cannot be left behind – I have been describe by a friend as being an educator to a generation that does not want to be educated,” to “seeing students successfully engage with certain types of activities motivates me to change my style/methodology to increase motivation more often, which in turn motivates more students to engage. Certainly my change in attitude and motivation is clear to see.

Pre and postintervention colleague observations provided the last data set regarding the effects of incorporating the indicated NGSS practices on my teaching and motivation. The colleague observation form contained four Likert scale responses with explanations and three additional open-ended questions. Results of the Likert scale responses are show below in Figure 8.

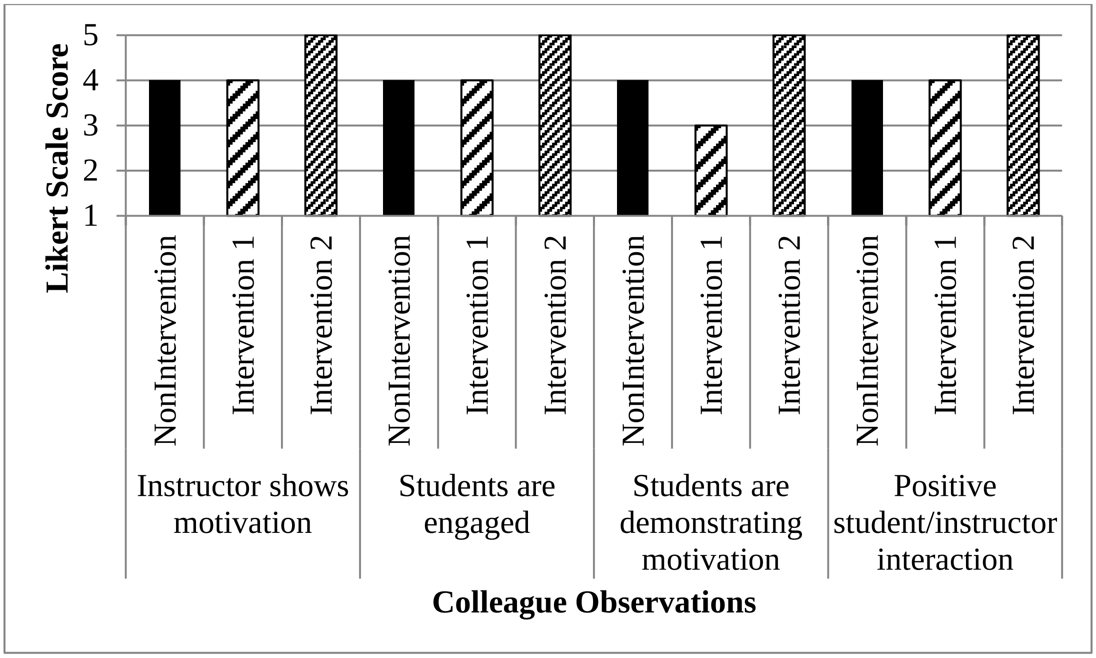


Figure 8. Likert scale of colleague's response to observation prompts. *Note* 1 = strongly disagree and 5 = strongly agree, (*N* = 1).

My colleagues' responses show a clear increase in the rating of all questions from the nonintervention unit to intervention #2. Intervention #1 shows consistent motivation on my part, but a decline in student motivation. I attribute this to the fact that the observation for treatment #1 occurred on the day that the students were engaged in creating a mental model of their understanding of inheritance of genetic traits on their own. Students struggled a lot with this activity. In response to the question, how does the motivation of the instructor change with the motivation of the students, my colleague wrote, "in order to keep the motivation of the students high, the instructor has to modify lessons to fit the learning/behavior style of the class – adaptation is the key to success" for his response during the nonintervention unit. During intervention #2 he wrote, “When the students become self-motivated, the instructor feels obligated to increase his own motivation.”

While there was a lot of extra work involved in creating the indicated NGSS practice-based activities, and some hardships with implementation, there can be little doubt that my overall engagement and motivation as an instructor increased as a result of incorporating these practices. In my postintervention instructor survey I wrote, “the more effort I put into creating or finding new activities the more engaged students become.”

My final data set revolved around determining the effects of incorporating the indicated NGSS practices on students' perception of instructor caring. Triangulation of data for this subquestion utilized my field notes and reflective journal, pre and postintervention surveys regarding instructors care for students, and student quotes from pre and postintervention surveys, as well as, colleague quotes from nonintervention and intervention observations.

In reviewing my daily field notes and reflective journal, I discovered that little data was actually recorded regarding the effect of incorporating NGSS practices on student perception of teacher care for students. I did record the following student comment in my daily field notes during intervention #1, “I feel like you know that I can do better than I am and that you want me to do better. That motivated me to increase my effort second semester.” In my reflective journal at the end of week two of intervention #2, I noted overhearing a student comment to another student, “he cares about his students, but he gets upset sometimes.”

Data from the pre and postintervention surveys regarding instructors care for students is recorded below in Figure 9.

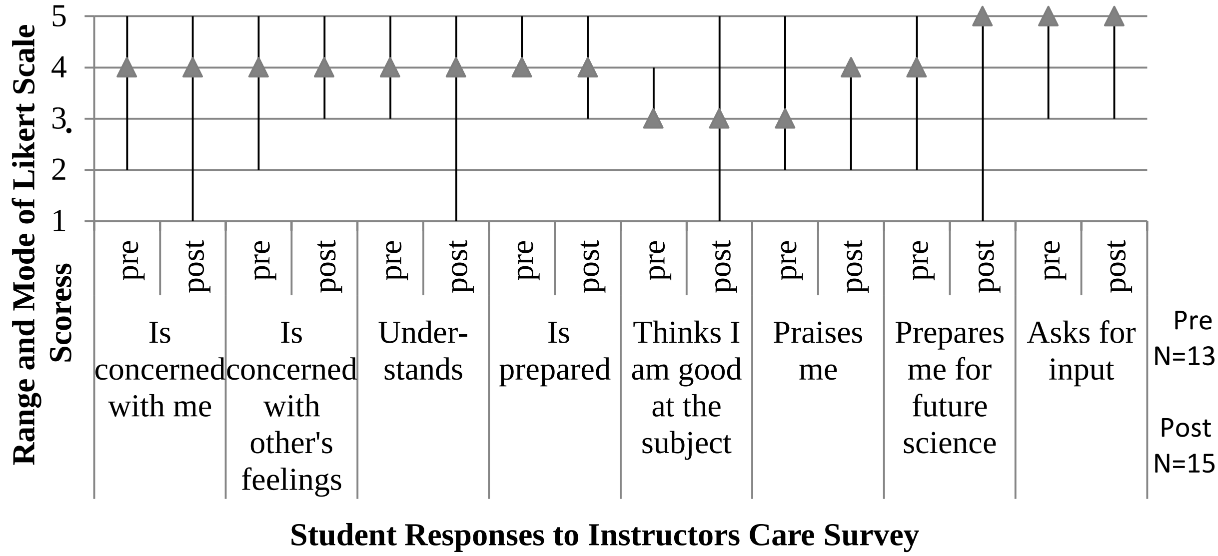


Figure 9. Range and mode (▲) of Likert scale responses of students to survey regarding instructors care for students. *Note* 1 = strongly disagree and 5 = strongly agree (*N* = 1).

The data shows little change in mode between preintervention and postintervention students perception of teacher caring other than an increase in range with more students indicating that they strongly disagree. I attribute this to the fact that only 13 surveys were completed for the preintervention and 15 were completed for the postintervention. Low survey numbers for the preintervention likely indicates that unmotivated students opted not to complete and turn in the survey while everyone completed and turned in the survey postintervention. While I feel that the overall data is not very conclusive, the increased number of surveys completed and turned in in my opinion indicates an increase in student desire to have their opinion heard which is indicative that they believe I care enough to want to see their opinions, and they are comfortable with me seeing them, even though they may not be positive. I believe the quality of the individual responses of students in the postintervention survey when asked to explain is of far more value. Student responses to the question, I feel my instructor is concerned with me, included, “I feel he has a true desire to see me learn and grow in his class," "he really pushes to help us understand," and "he wants us to do better, I can tell, he tries to get us to focus." Student responses to the question, I feel my instructor is concerned with other's feelings, included; "while he is not going to be riding you, he is always there if you have questions," and "he is always concerned with people's feelings."

The last data set for incorporation of the NGSS practices on student perception of instructor's care for students, in nonintervention and intervention units was my colleague's observations, which also contained little data. He did make the comment that "to design and prep the students for the arbitration case activity required a lot of individual motivation and caring on the part of the instructor."

The lack of data made analyzing the results regarding students' perception of the instructor's care for students impossible. I attribute this to a lack of properly prepared data collection instruments and must therefore determine that the data regarding determining the effects of incorporating the indicated NGSS practices on students' perception of instructor caring is inconclusive.

INTERPRETATION AND CONCLUSION

Data were analyzed to answer my focus question regarding the effects of incorporating three specified practices of NGSS on students' understanding of biological concepts. Evaluation of the data collected from all three units suggests the incorporation of the specified NGSS practices assisted students in developing a greater conceptual understanding of biological concepts than traditional methods, although their perception of their understanding may have declined, particularly among low achieving students.

Students also appeared to be more motivated and engaged during both of the intervention units than they were during the nonintervention unit. It appears that activities incorporating the NGSS practices inspired students to work harder and participate more. Creating models was difficult but beneficial for student understanding of concepts and activities that directly incorporated the selected strategies, such as the DNA model and the arbitration case, motivated them to participate. This created an educational environment which engaged and motivated both the students and I.

Reviewing the data regarding my motivation and engagement showed that my motivation remained fairly consistent throughout the intervention, but that both my attitude and my engagement towards teaching improved during the intervention units. Clearly incorporating the selected NGSS practices inspired me to work harder and engage more with my students.

A review of the data regarding the effects of incorporating the indicated NGSS practices on students' perception of instructor care for students, revealed a lack of data and results were inconclusive. While based on my own observations, I feel that students changed their perception of me as a caring instructor, data supporting this feeling are lacking and no conclusive results can be drawn.

There were several issues with data collection for this project that I feel could be improved in the future. The first would be in the area of pre and postunit assessments. Students struggled a lot with my pre and postunit assessments because of the inclusion of an abundance of scientific vocabulary. While I did this on purpose, I realized in watching students take the assessments that many simply gave up because they couldn't understand the language while interviews later revealed that they understood the concepts, but had not mastered the vocabulary. I feel that some methods of more direct immersion in scientific vocabulary, such as the use of word walls or vocabulary building games, would empower students to recognize relevant scientific vocabulary while ignoring irrelevant vocabulary such as scientific names and would help them not only on my assessments but on state and national assessments as well. Additionally, more attention to details in developing the background information for these assessments is also needed. I discovered during the administration of the posttreatment assessment for intervention #2 that critical information needed for students to be able to answer the question had not been included in the background. The refinement of these assessments will help to improve the quality of data collected in order to better assess the impact of incorporating the indicated NGSS practices.

Another issue revolved around timing and while part of that was a result of my own decision to incorporate some additional last minute material into intervention #1, much of it was out of my control due to weather issues or school wide activities that I was unable to predict or anticipate in my plans. Regardless of how well something is planned out, there are always issues outside of our control and flexibility is required on the part of the instructor to address these issues.

The final issue I encountered revolved around my failure to include prompts directly related to student's perception of instructor care for students into my field notes, reflective journal or my colleagues' observation form. Tweaking these forms to include prompts directly related to this question would have generated more data and allowed for a conclusive result.

In reviewing student responses, one area that became evident that I had not considered in the project was students' perception of my direct interaction with them. Student responses showed that many students felt I have little to no direct communication or praise for them, and this is an area which I would like to explore and address more thoroughly in the future.

Refinement of the various data collection tools and incorporating more flexibility into the timing of the units to allow for unpredictable issues will help improve the quality of the data to better assess the impacts of incorporating NGSS practices into the classroom.

VALUE

Participation in this capstone project has provided me with the opportunity to grow professionally by exploring new education strategies. Until recently I had only touched the surface of incorporating practices similar to those found in NGSS into the classroom. Developing and implementing this project has allowed me to work specifically with those practices, reflect on my personal values and my role as an instructor, and has made me more aware of ways to provide a more motivating and engaging learning experience to my students. As a result, I have come to see the value of incorporating these NGSS practices into the classroom.

The use of the specified NGSS practices within the classroom provided me with the opportunity to explore a methodology which more directly involves students in doing science rather than learning about science. This method of instruction engages students within the classroom in actually doing science themselves and requires them to participate in learning about, developing and evaluating real scientific models and theories. This promotes an engaging and fun environment that has real life implications and relevance.

Incorporation of these NGSS practices benefits students by providing a meaningful learning experience in which students come to understand that scientific explanations are constantly changing as we modify our understanding and generate new knowledge through experimentation and observation. While incorporation of the three chosen NGSS strategies is most likely not the only method of increasing student engagement and motivation, research indicates that is has real value in the science classroom and will help provide students with the tools they need in a subject which is often difficult for them to understand or see the relevance of.

As an educator and instructor, this project has been very beneficial to my attitude and motivation towards teaching. It has changed my attitude toward NGSS as a mandated curriculum change, as well as, towards teaching in general. It has allowed me to realize that the moments I enjoy most and which motivate me most as an instructor, are those in which students are motivated and engaged and are experiencing success in understanding the curriculum. Seeing my students engage and become motivated further motivates me to continue to develop activities based on incorporating these strategies and to share my experiences with others.

As I look ahead and begin planning for next year, I am already looking for new ways to implement developing and using models, using mathematics and computational thinking, and engaging in argument from evidence into other content areas within my curriculum. Currently most units in the existing biology curriculum are more traditionally taught and involve little use of these practices. I will need to incorporate more practice with models and classroom practice with model development before asking students to independently develop models of their understanding. I've already began discussing implementing more of these practices with the biology PLC team I work with, and I hope that sharing my findings from this project will make them more receptive to adopting more of the NGSS practices and the NGSS curriculum as a whole.

I believe that these NGSS practices can be adopted into any science classroom regardless of grade level and I am excited about the possibilities. However, I also recognize that development of lessons that incorporate these practices is very time consuming and that I tend to slip back into my traditional teaching strategies. Additionally, with current legislation in Wyoming restricting the funding for NGSS curriculum, its' future in the state of Wyoming is yet to be determined. Because NGSS is so new, I see that development of activities and teacher training in the use of NGSS practices is an area of weakness. As additional lesson development occurs and teacher training in using the practices of NGSS becomes more available at a national level I hope to be able to participate and benefit from them, and I'm sure that other teachers will as well.

My capstone project has made me reevaluate my traditional teaching methods and classroom activities as well as the ways that I view and interact with my students. I am convinced of how important it is to directly involve students in doing science using these NGSS practices regardless of their adoption by my state. This project has helped me develop professionally and realize that I cannot be complacent with my traditional teaching strategies. It is my job as an instructor to reach all of my students, to motivate them to engage in their learning, as well as to provide them with the tools they need to become successful which in turn will motivate me to improve my own teaching and practices. I intend to continue to explore NGSS practices to better engage and motivate my students.

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APPENDICES

APPENDIX A

PROJECT TIMELINE

Project Timeline

Nonintervention Unit: Bacteria

January 6, 2014: Bacteria biodiversity, **started preunit concept interviews, begin instructor field notes**

January 7, 2014: Direct instruction, bacteria introduction, **preunit capstone project target assessment**

January 8, 2014: Complete bacteria introduction and exposure of culture plates for Application #3A; Culturing and Staining Bacteria

January 9, 2014: 24 hour bacterial colony count for Application #3A and begin Reading Application #3D; Genetically Engineered Bacteria.

1st observation by colleague

January 10, 2014: Biodiversity Quiz on bacteria, 48 hour bacterial colony count for Application #3A, and bacteria diseases worksheet

January 11, 2014: Instructor reflective journal with prompts

January 13, 2014: Gram staining of bacteria colonies for Application #3A

January 14, 2014: Completion of Application #3A and review for semester exams

January 15, 2014: Semester Exams and **preintervention biology engagement/motivational questionnaire**

January 17, 2014: Instructor reflective journal with prompts

January 20, 2014: Postunit capstone target assessment, collect preintervention student concept surveys, started postunit concept interviews and preintervention nonconcept interviews

January 21, 2014: Review semester exams and **preintervention survey regarding instructor's care for students**

Intervention Unit 1: The Molecular Basis of Genetics

January 22, 2014: Preunit student concept survey and started preunit concept interviews

January 23, 2014: *One Ugly Pooch* article with birthday card

January 24, 2014: Genetic engineering PPT, questionnaire on benefits and dangers of selective breeding and genetic engineering, homework questionnaire on personal thoughts and opinions regarding selective breeding and genetic engineering

January 25, 2014: Instructor reflective journal with prompts

January 27, 2014: Began *Before* explanatory model with text and "gotta-have" explanations

January 28, 2014: Completed *Before* explanatory model with text and “gotta-have” explanations

January 29, 2014: Review of model with comments, **intervention preunit capstone project target assessment**

January 30, 2014: introduction of molecular structure of DNA and molecular DNA and replication worksheet

January 31, 2014: Review Molecular DNA and replication worksheet, and cooperative work on summary table/revision of model

February 1, 2014: Instructor reflective journal with prompts

February 3, 2014: Began DNA replication modeling lab

February 4, 2014: Completed DNA replication modeling lab and introduce RNA structure

February 5, 2014: *During* explanatory model with text and “gotta-have” explanations

2nd observation by colleague

February 6, 2014: Introduce protein synthesis (videoclip) and began transcription, translation, and protein synthesis worksheet

February 7, 2014: Continue transcription, translation and protein synthesis worksheet, cooperative work on summary table/revision of model,

February 8, 2014: Instructor reflective journal with prompts

February 10, 2014: Complete transcription, translation and protein synthesis worksheet and formative quiz over DNA/RNA structure and function

February 11, 2014: Review DNA/RNA structure and function quiz and introduce meiosis

February 12, 2014: Continue meiosis (computer lab)

February 13, 2014: Complete meiosis

February 14, 2014: Meiosis quiz, and cooperative work on summary table/revision of model

February 15, 2014: Instructor reflective journal with prompts

February 17, 2014: Review Meiosis quiz, prep for model

February 18, 2014: *After* explanatory model with text and “gotta-have” explanations

February 19, 2014: Motivational talk and comparison of *before/after* models

February 20, 2014: [Early Release] Snork protein synthesis activity, **began intervention postunit #1 concept and nonconcept interviews**

February 21, 2014: [Make-up Snow Day/Early Dismissal] Begin Snork protein synthesis activity presentations

February 22, 2014: Instructor reflective journal with prompts

February 24, 2014: Complete Snork protein synthesis activity presentations, **post intervention biology engagement/motivational questionnaire, collect postintervention concept survey,**

February 25, 2014: Intervention #1 postunit capstone project target assessment

Intervention Unit 2: Principles of Genetics

February 26, 2014: PPT introduction to Gregor Mendel and his work, **started intervention preunit concept interviews**

February 27, 2014: Mathematical probability lab

February 28, 2014: Complete mathematical probability lab and **preunit student concept surveys**

March 1, 2014: Instructor reflective journal with prompts

March 3, 2014: Preunit capstone project target assessment Punnett square model and generation of "*gotta-have*" checklist

March 4, 2014: Introduce monohybrid problems

March 5, 2014: Challenge problem and complete monohybrid problems

March 6, 2014: Challenge problem and introduce testcrosses

March 7, 2014: Challenge problem and complete testcross problems

March 8, 2014: Instructor reflective journal with prompts

March 10, 2014: Challenge problem and introduce incomplete dominance and codominance problems

March 11, 2014: Challenge problem and omplete incomplete and codominance problems

March 12, 2014: Challenge problem and introduce dihybrid problems

March 13, 2014: Challenge problem and complete dihybrid problems

March 14, 2014: final challenge problem presented, roles assigned for final challenge problem

March 15, 2014: Instructor reflective journal with prompts

March 17, 2014: Research and preparation of case

March 18, 2014: Research and preparation of case

March 19, 2014: Complete research and preparation of case

March 20, 2014: Presentation of claims and rebuttals

3rd observation by colleague

March 21, 2014: Arbitrator decision with evidentiary reasoning, good vs. bad evidence discussion, **collect student postintervention concept surveys**

March 22, 2014: Instructor reflective journal with prompts

March 24-28, 2014: Spring Break

March 31, 2014: review principles of genetics, **postintervention engagement/motivation questionaires, started intervention #2 postunit concept interviews and postintervention nonconcept interviews, postintervention survey regarding instructor's care for students**

April 1, 2014: postunit capstone project target assessment and final Instructor reflective journal with prompts

Project complete on April 7, 2014

APPENDIX B

PREUNIT BACTERIA ASSESSMENT

Preunit Bacteria Assessment

Aubrey and Tory are setting up a 100 gallon aquarium for African cichlids. The first thing they do is cycle the tank. Cycling the tank means establishing populations of nitrifying bacteria in the aquarium that carry out the nitrogen cycle; converting ammonia (NH_3) first into nitrite (NO_2-) and then into nitrate (NO_3-). To begin this process, they add ammonia to the tank, and test ammonia, daily till they start to see ammonia levels decline and nitrite levels start to rise. They continue the process by adding ammonia and testing until ammonia levels are consistently at zero, nitrite levels have also fallen, and nitrate levels begin to rise. At that point, the tank is considered cycled. A large scale water change then removes the excess nitrates and the tank is considered ready for fish.

They purchase and add 10 African cichlids of a *Pseudotropheous sp.* to the tank, which do well for several days. Unfortunately, one of the Africans starts to show symptoms of Malawi Bloat, one of the most prevalent bacterial caused diseases afflicting aquarium-kept African cichlids. Malawi Bloat is a deadly, noncontagious disease whose initial symptoms are a loss of appetite, followed by abdominal swelling and an increased respiratory rate. Symptoms only appear in the later stages of the disease, and by the time they appear damage has already been done to the liver and kidneys. Death results in 24 to 72 hours.

The fish dies, but its death goes unnoticed, and the fish begins to decompose. As the heterotrophic bacteria in the tank begin to break down the fish, they begin releasing large amounts of nutrients consisting of nitrogen and phosphates into the water. This release of nutrients results in an outbreak of cyanobacteria, also known as blue-green algae. Blue-green algae is a nitrogen-fixing bacteria which converts atmospheric nitrogen (N_2) from the air into ammonia, which it then converts into amino acids resulting in massive growth of algae known as an algae bloom. The blue-green alga eventually manages to take over large areas of the aquarium causing it to turn a nasty green and look very unsightly. The mass of algae on the top of the aquarium water cuts of the oxygen supply to the tank and eventually results in the remaining fish dying as well.

1. Use a diagram to identify the different types of bacteria present in the aquarium and the role they play. Center the diagram on an outline sketch of an aquarium.
2. Explain the role that bacteria played in the death of the first fish.
3. Draw a flow chart that illustrates the various roles that the bacterium in the aquarium plays in the nitrogen cycle starting with atmospheric nitrogen.
4. Using the information provided about bacteria in the scenario and the diagram you drew above as evidence; defend the statement that bacteria are both beneficial and detrimental to the aquarium.
5. Design a plan to return the aquarium to a state that is suitable for fish to inhabit again.

APPENDIX C

APPLICATION #3A; CULTURING AND STAINING BACTERIA

Culturing and Staining Bacteria

Application # 3 A

Bacteria are unicellular prokaryotes, ranging in size from 1 to 10 micrometers (remember that one micrometer is equal to one thousandth of a millimeter). While you can't see them, bacteria exist almost everywhere on Earth; the objects you are currently touching and even your skin has bacteria on it. Bacteria can be cultured and grown on Petri dishes containing a nutrient source, known as agar, on which bacteria will be grown on readily.

The most widely distributed of all organisms, bacteria are identified based on a number of characteristics. One way to distinguish bacteria is by shape; bacteria that are rod-shaped are called bacilli, bacteria that are spherical-shaped are called cocci, and bacteria that are spiral-shaped are called spirilla. Another method used to distinguish bacteria is the groupings in which they grow; bacteria that grow in pairs are identified with the prefix bi-, bacteria that grow in chains are identified with the prefix strepto-, and bacteria that grow in clusters are identified with the prefix staphylo-. Yet another method of identification is by use of a staining method called a Gram stain; Gram positive bacteria, which contain thick peptidoglycan walls stain purple, while Gram negative bacteria, which have thin peptidoglycan walls inside an outer lipid layer stain pink.

In this activity, you observe some of the characteristics of bacteria, You will also observe how bacteria grow and stain and examine bacteria colonies.

Objectives:

During this investigation, you will

1. Culture bacteria on agar plates from environmental sources
2. Conduct a Gram stain
3. Become aware of the omnipresence of bacteria

Procedure:

I. Culturing Bacteria

Use a damp Q-tip to swipe the surface of the environment of your choice, or that indicated by the laboratory facilitator. Some suggested environments for exposure include: soil, tabletops, the restroom (floor, toilet seat, flush handle, etc.), coins, animals (**NO HUMANS**), buttons on pop machines, computer keyboards, and inside a refrigerator. Students are encouraged to be creative and come up with their own culture sources. After swiping the surface, lift one side of the culture lid and **gently** inscribe your first initial on the agars surface (**caution: pushing too hard with force the Q-tip into the agar, ruining the culture**).

After exposing the plate, use a permanent marker to label your agar plate with your initials and the environment to which you exposed it.

Plates will be incubated upside down for 24 hours at 30°C. After 24 hours they will be examined for the presence of bacteria colonies, and any existing colonies will be counted (**caution: not all colonies on a plate will be bacteria, light, fluffy cloudlike colonies are fungi**). Bacteria counts for the entire class will be entered into the data table. They will then be incubated again for 24 or 48 hours and reexamined and recounted (**caution: after examining your culture, wash your hands thoroughly with soap and water – if the culture dish was opened, disinfect your lab table as well**).

Equipment:

- Sterile Petri dishes with nutrient agar
- Sterile cotton swabs
- Permanent markers
- Inoculating loops
- Bunsen burners
- Microscope slides
- Wash bottles of decolorizing alcohol
- Grams Iodine solution
- Safranin counterstain

II. Gram Staining Bacteria

Caution: When conducting this portion of the application wear safety glasses at all times and use extreme caution with the bacteria cultures, Bunsen burners, inoculating loops, stains, and when handling

heat-fixed microscope slides. Assume all cultures are pathogenic (disease-causing).

In order to prepare your smear, sterilize an inoculating loop in the Bunsen burner by holding it in the flame until it is red hot, allow it to cool for 10 to 15 seconds, and then use it to place a loopful of distilled water on a clean slide. Sterilize your inoculating loop again, allow it to cool, and remove a small amount of the bacteria culture (**Caution: do not dig into the agar, scrape the surface gently, so you are removing only the bacteria**). Mix the culture material and distilled water with a circular motion, and spread it over the center portion of the slide. Immediately sterilize the inoculating loop again, turn off the Bunsen burner and allow the smear and loop to air dry (**Caution: do not touch the bacterial smear to determine if it is dry. Always avoid direct contact with bacteria cultures!**). After the smear has dried, attach a slide holder onto the end of the slide, and fix the smear by passing the slide through the Bunsen burner flame, smear up, three times (**Caution: fix the smear with care – excessive heat will burn off the smear or cause the slide to fracture**). Heat fixing the slide kills the bacteria and attaches, or "fixes", the bacteria to the slide. Allow the smear to cool for a couple of minutes before moving to the staining table (**Caution: allow plenty of time for the slide to cool – glass slides hold heat for a long time!**)

After the smear has cooled, you will need to move to the staining table. Begin staining your smear by flooding it with crystal violet stain for one minute. After one minute, briefly rinse the slide with distilled water (**Caution: not more than five seconds, or you may wash off your smear or too much of the stain**). Then cover you smear with Gram's Iodine solution for minute and again after one minute, rinse with water. Decolorize you smear by flooding it with decolorizing alcohol for several seconds. Pour off the excess alcohol and repeat the decolorization process again (twice more if you have a thick, heavy smear). Rinse the smear again with water. Counter stain the smear with safranin counterstain for 30 seconds and rinse again with water. Finally gently blot your smear dry with absorbent lint free paper (**Caution: do not wipe dry! Doing so will cause the smear to rub off!**).

Examine the prepared smear under the microscope. Gram positive bacteria will retain the initial stain and appear blue to purple or black. Gram negative bacteria will decolorize with the alcohol and retain the second stain, appearing red or reddish pink.

After examining the slide, return both the slide and bacteria culture to the laboratory facilitator for proper disposal. Wipe down the surface of your lab table with a disinfectant and allow it to air dry. Wash your hands thoroughly with soap and hot water!

Culturing and Staining Bacterial *Data Sheet*

Table 9A – 1; Bacteria Colony Counts						
Student Initials	*Plate No.*	*Surface Cultured*	*Growth (24 hours)*		*Growth (48 hours)*	
			Neg.	*Pos. (#)*	*Neg.*	*Pos. (#)*
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					
	11					
	12					
	13					
	14					
	15					
	16					
	17					
	18					
	19					
	20					
	21					
	22					
	23					
	24					

ANALYSIS

Answer the following questions;

1. Identify whether your bacteria culture was gram positive or gram negative.

2. Based on the investigation, what conclusions can you arrive at about the distribution of bacteria in our world?

3. A scientist finds a new organism but is unsure to which kingdom it belongs. The organism is unicellular, has a cell wall containing peptidoglycan, has a circular DNA molecule and ribosomes, but it lacks a nucleus. Based on those characteristics, to which kingdom does it belong? Explain.

4. Suppose that bacteria lost the ability to fix nitrogen. How would this affect other organisms?

5. Bacteria that live on teeth produce an acid that causes decay. Why do people who do not brush their teeth regularly tend to have more cavities then those who do?

6. You are writing a science article entitled "Bacteria in the Biosphere" for the local newspaper. Explain the role bacteria play in the environment. Describe both the benefits they provide and the harm they can cause.

APPENDIX D

POSTUNIT BACTERIA ASSESSMENT

Postunit Bacteria Assessment

The human body is a virtual microbiome of various types of bacteria found on the surface of skin, in saliva, in the mouth, and within the digestive tract. This microgarden of thousands of different species is thought to account for 1 to 3% of our normal body mass, most of which is found in the large intestine.

Skin is covered by roughly a thousand species of bacteria which are usually non-pathogenic and either commensalistic (not harmful to their host) or mutualistic (offer a benefit). However when these microbes grow beyond normal levels due to a weakened immune system or injury, they can cause infections or disease. For example, anaerobic (living in the absence of oxygen) *Staphylococcus sp.,* spherical, Gram positive bacteria which can survive aerobically or anaerobically, occurs in grape-like clusters and is typically harmless, but antibiotic resistant strains can cause deadly infections and their toxins are a common source of food poisoning.

The mouth teems with various types of bacteria including anaerobic *Actinomyces sp.,* rod-shaped, Gram positive bacteria which are part of the sticky material in the mouth. These bacteria produces enzymes which aid in degrading organic plant material, but this sticky material can harden to form plaque and if not removed secrets acid that dissolves tooth enamel.

Ninety-nine percent of heterotrophic bacteria found in the gut are anaerobes that aid in the digestion of food. Anaerobes such as *Escherichia coli,* Gram negative, rod-shaped bacteria aid in digestion of substances we couldn't normally digest like carbohydrates, but outside the gut are a common cause of food poisoning. Other bacteria produce vitamin K and synthesize vitamin B. Anaerobic *Bacteriod sp*., Gram negative, rod-shaped bacteria assist in breaking down food to producing valuable nutrients and energy the body needs. However when overabundant, these *Bacteriod sp*. are associated with the production of tumors and when introduced to areas outside the gut can cause serious infections.

Aerobic *Streptomyces sp.,* Gram positive, filamentous bacteria commonly found in soil produce over two-thirds of the naturally occurring antibiotics used by humans to fight bacterial infections.

1. Use a diagram to identify the different types of bacteria present on, in and used by the human body and the role they play. Center the diagram on an outline sketch of a human body.
2. Explain the role that bacteria play in causing tooth decay.
3. Draw an outline sketch of the gastrointestinal tract starting in the mouth that illustrates the various roles that bacteria play on food digestion.
4. Using the information provided about bacteria in the scenario and the diagram you drew above as evidence; defend the statement that bacteria are both beneficial and detrimental to humans.
5. Hypothesize what would happen if sewage waste water containing *E. coli* was accidently released into the drinking water supply of a small community.

APPENDIX E

PRE AND POSTINTERVENTION STUDENT CONCEPT SURVEY

Pre and Postintervention Student Concept Survey

Please complete this survey honestly. Participation is voluntary and will not affect your grade. There are no wrong or right answers, but your answers will help me in becoming a better instructor for you. Please be straight forward and detailed with your responses.

Please use the following scale to select your choices for the statements below:
SA: Strongly agree A: Agree U: Unsure D: Disagree SD: Strongly disagree

Circle one choice for each item:

1. I can succeed in (Topic of Study).	SA	A	U	D	SD
2. I am confident that I understand (Topic of Study).	SA	A	U	D	SD
3. I can use models, math, and supporting evidence to solve problems in (Topic of Study).	SA	A	U	D	SD
4. (Topic of Study) is too hard.	SA	A	U	D	SD

What class activities helped you learn this material the best? Explain.

5. (Topic of Study) is interesting.	SA	A	U	D	SD
6. (Topic of Study) is important.	SA	A	U	D	SD
7. I want to succeed in (Topic of Study).	SA	A	U	D	SD
8. I think doing well in (Topic of Study) is important.	SA	A	U	D	SD
9. I see myself pursuing a career in or relating to (Topic of Study).	SA	A	U	D	SD
10. I want to learn more about (Topic of Study)	SA	A	U	D	SD

What are some additional areas related to this topic of study that you would like to explore further? Explain.

11. The activities relating to (Topic of Study) trigger my curiosity.	SA	A	U	D	SD
12. I enjoy learning about (Topic of Study)	SA	A	U	D	SD
13. I like solving (Topic of Study) problems.	SA	A	U	D	SD

14. The activity/activities I enjoyed the most related to this topic of study were:

15. The activity/activities that frustrated me the most related to this topic of study were:

APPENDIX F

PRE AND POSTINTERVENTION BIOLOGY ENGAGEMENT/MOTIVATION QUESTIONNAIRE

Pre and Postintervention Biology Engagement/Motivational Questionnaire

Please complete this questionnaire honestly. Participation is voluntary and will not affect your grade. There are no wrong or right answers, but your answers will help me in becoming a better instructor for you. Please be straight forward and detailed with your responses.

Please use the following scale to select your choices for the statements below:
SA: Strongly agree A: Agree U: Unsure D: Disagree SD: Strongly disagree

Circle one choice for each item.

1. I think I am good at Biology. SA A U D SD
   Support your answer with two examples:

2. I enjoy Biology. SA A U D SD
   Why or why not:

3. When we work individually, I concentrate on the task. SA A U D SD
   Please explain your response:

4. When we do group activities, I concentrate and help with the task. SA A U D SD
   Please explain your response:

5. When the teacher instructs the class, I pay attention. SA A U D SD
   Please explain your response:

6. I can understand new ideas related to Biology quickly when they are introduced in the classroom using models, math and supporting evidence. SA A U D SD
   Please explain your response:

7. What do you find most enjoyable about biology? Please explain your response with an example.

8. What do you find most frustrating about biology? Please explain your response with an example.

9. Was using mathematics, models, and/or supporting evidence motivating and/or engaging in your study of biology? Please explain your response with an example.

10. [Preintervention only] What motivates you to learn new concepts in biology? Please explain your answer with examples.

10. [Postintervention only] What is the biggest change that you have noticed in your own attitude or motivation towards biology after learning to use math, models, and supporting evidence to understand biological concepts? Please explain your answer with examples.

11. Is there any other question you think I should have asked that is important? Please ask and explain your answer.

APPENDIX G

A SURVEY REGARDING INSTRUCTOR’S CARE FOR STUDENTS

A Survey Regarding Instructor's Care For Students

Please complete this survey honestly. Participation is voluntary and will not affect your grade. There are no wrong or right answers, but your answers will help me in becoming a better instructor for you. Please be straight forward and detailed with your responses.

Please use the following scale to select your choices for the statements below:
SA: Strongly agree A: Agree U: Unsure D: Disagree SD: Strongly disagree

Circle one choice for each item.

1. I feel my instructor is concerned with me. SA A U D SD
   Please explain your response:

2. I feel my instructor is concerned with other's feelings. SA A U D SD
   Please explain your response:

3. I feel my instructor is understanding SA A U D SD
   Please explain your response:

4. I feel my instructor has planned for and is well prepared for classroom activities. SA A U D SD
   Please explain your response:

5. My instructor thinks I am good at (Topic of Study). Please explain your response:	SA	A	U	D	SD
6. My instructor often praises me. Please explain your response:	SA	A	U	D	SD
7. My instructor prepared me adequately for future science classes. Please explain your response:	SA	A	U	D	SD
8. My instructor asks us to give input on making the class better. Please explain your response:	SA	A	U	D	SD

APPENDIX H

BENEFITS AND DANGERS INHERIT IN SELECTIVE BREEDING AND GENETIC ENGINEERING QUESTIONNAIRE

Benefits and Dangers Inherit in Selective Breeding and Genetic Engineering
Questionnaire

1. Is selective breeding and genetic engineering beneficial to society?

   On what evidence do you base your answer?

2. Is it appropriate to selectively breed or genetically engineer animals such as mice, dogs and cattle?

   On what evidence do you base your answer?

3. Is it appropriate to selectively breed or genetically engineer plants such as corn, roses, and tomatoes?

   On what evidence do you base your answer?

4. Is it appropriate to selectively breed or genetically engineer humans?

   On what evidence do you base your answer?

APPENDIX I

PERSONAL THOUGHTS AND ATTITUDES REGARDING BOTH SELECTIVE BREEDING AND GENETIC ENGINEERING QUESTIONNAIRE

Personal Thoughts and Attitudes Regarding both Selective Breeding and Genetic Engineering Questionnaire

1. Is it appropriate to grow genetically modified corn (GMOs) that will grow in drought conditions in order to provide food to natives of Africa were hunger is prevalent?

   On what evidence do you base your answer?

2. Is it appropriate to genetically modify pigs to serve as human organ donors to provide organs to humans that are dying as a result of organ failure?

   On what evidence do you base your answer?

3. Is it appropriate to genetically modify humans to cure a genetic disease or disorder which will inhibit their quality of life or result in an early death?

   On what evidence do you base your answer?

APPENDIX J

PREUNIT MOLECULAR BASIS OF GENETICS TARGET ASSESSMENT

Preunit Molecular Basis of Genetics Target Assessment

Dwarfism is a medical disorder, and is typically defined in humans as an adult height of less than 4 ft. 10 in. The most common cause of dwarfism is genetic mutations. Short stature can be inherited without being the result of a mutation, and short stature in the absence of a mutation is not generally considered dwarfism. Short parents tend to produce short children; parents with dwarfism may produce children of average height, if the mutation that causes their dwarfism is not passed on.

The most common and recognizable form of dwarfish in humans is achondroplasia, which is caused by a mutation on chromosome four, and accounts for 70% of dwarfism cases. Individuals with achondroplasia dwarfism have short stature (an average height of 4 ft. 3.5 in. in males and 4 ft. 0.4 in. in females), limbs that are proportionally shorter than the abdominal area, increased spinal curvature, and a distortion of skull growth that typically results in a larger head than average and characteristic facial features. Some achondroplastic dwarfs are as short as 2 ft. 0.7 in.

Achondroplasia occurs as a sporadic mutation in approximately 80% of cases or it may be inherited as a dominant genetic disorder caused by the presence of a faulty allele. The mutation that causes achondroplasia dwarfism pushes the fibroblast growth factor receptor 3 gene (*FGFR3*) to work constantly, resulting in an abnormality of cartilage formation that prevents bone growth and results in severely shortened bones. If both parents have and pass on the mutant gene, the result is fatal, either before or shortly after birth; the resulting children will rarely live past a few months of age.

No known treatment for achondroplasia dwarfism currently exists, even though the mutation has been identified. Another cause of human dwarfism is growth hormone deficiency (GHD), caused by mutations in one of three genes. One of these is the *GHRGHR* gene which triggers the production of growth hormone (GH) and its release. GH is an enzyme (protein), which stimulates growth and cell reproduction. If this hormone is missing, stunted or even halted growth becomes apparent. GHD dwarfism is treatable through growth hormone replacement or injections of growth hormones.

GH injections have been tested on individuals with achondroplasia dwarfism; unfortunately it is beneficial only within the first and second year of therapy, and after the second year, beneficial bone growth decreases. Therefore it is not a satisfactory long term treatment. Gene based therapy may possibly serve as a future treatment option.

Use your model and the information above to answer the following questions;

1. Identify different genes and the role they play in determining human dwarfism.
2. Explain why the genetic disorders that cause dwarfism can be difficult to treat.
3. Create a flow chart starting with DNA that illustrates the role of one of these genes in producing human dwarfism.
4. Using the information provided about human dwarfism in the scenario and the model you created as evidence; defend the statement that a single mutation can be both detrimental and deadly.
5. Hypothesize other unique effects that other mutations occurring in humans might have on human growth patterns.

APPENDIX K

POST APPLICATION QUESTIONS

Post Application Questions

Analysis

1. Where would you find the DNA this model represents in a real cell?

2. Name the two chemicals that form the sides of the double helix. Explain how to distinguish between them without using color.

3. Give the chemical name for the type of bond which connects these molecules.

4. Give the chemical name for the type of bond which forms the rungs that occur between complementary nitrogen base pairs.

5. Where the two copies of DNA that you created during the semi-conservative replication phase of the activity identical to each other? Explain.

6. Using this activity as evidence, explain why scientists create and use models.

Conclusion

On a separate sheet of scrap paper, using the application objectives and evidence draw from the activity, write out the answer the following; who, did what, to whom or what, when, where, how, and why. Then here in the lab, using formal writing style, in your own words, write a single paragraph that describes what you learned by combining the answers you gave to the following; who, did what, to whom or what, when, where, how, and why. Start with the statement, **"By performing this lab experiment I . . ."**

APPENDIX L

FORMAT FOR STUDENT MODEL COMMENTS

Format for Student Model Comments

Students were required to use the following sentence frames in writing their sticky notes;

Orange (Add to the Model);

- We need to add [describe what needs to be added] because [list evidence from activity, reading, discussions or other groups' models].
- We think ___________________ supports our model, but it also tells us that [describe what needs to be added] should be added to make it even more accurate.

Green (Revise the Model):

- We need to change [description of what you need to change] because [list evidence from activity, reading, discussions or other groups' models].
- We used to think ________________, but now we think ________________, because [list evidence from activity, reading, discussions or other groups' models].
- We think ________________ contradicts ________________ in our original models because [list evidence from activity, reading, discussions or other groups' models].

Pink (Questions About the Model)

- We are wondering about [part of model] because [list evidence from activity, reading, discussions or other groups' models].
- We think that if we knew ________________, it would help us explain ________________ because [list evidence from activity, reading, discussions or other groups' models].

Reference: Adopted from:

Windschitl, M. & Thompson, J.J. (2013). The modeling toolkit: making students thinking visible with public representations. *The Science Teacher*, *80*(6), 63-69.

APPENDIX M

POSTUNIT MOLECULAR BASIS OF GENETICS ASSESSMENT

Postunit Molecular Basis of Genetics Target Assessment

Human eye color is an inherited trait, however the genetics of eye color are complicated and eye color is determined by the more than one gene. The belief that blue eye color is a simple recessive trait has been shown to be incorrect. The actual number of genes that contribute to eye color is currently unknown, but as many as sixteen have so far been associated with eye color inheritance. Two of these eye color genes are the genes *OCA2* and *HERC2*, which have been shown to be two of the main genes associated with eye color. Both are found on Chromosome 15. The genetics of eye color are so complex that almost any parent-child combination of eye colors can occur.

The *HERC2* gene regulates *OCA2* expression, and different variations are strongly associated with blue and green eyes. A specific mutation within the *HERC2* gene is partly responsible for blue eyes.

Variations in eye color from brown to green are explained by the amount of melanin in the iris and brown-eyed individuals have considerable variation in the area of their DNA that controls melanin production. But blue-eyed individuals, in contrast, have only a small variation in the amount of melanin production in their eyes. The specific genetic mutation in the *HERC2* gene, which affects the expression of the *OCA2* gene in our chromosomes, reduces the production of melanin in the iris, effectively diluting brown eyes to blue. If the *OCA2* gene were destroyed or shut off and melanin production were completely shut down, human eyes would be pink, a condition commonly known as albinism.

Research has shown that the specific genetic mutation in *HERC2* which affects the expression of the *OCA2* gene took place 6-10,000 years ago resulting in the creation of a “switch” which reduces the production of melanin, thus turning off the ability to produce brown eyes. The inheritance of this mutation in the exact same spot in our chromosomes indicates that the ancestry of people with blue eyes can be traced back to a single common ancestor.

The mutation of brown to blue neither increases nor decreases a human’s chance of survival. Rather, it is simply one of a number of mutations such as hair color, baldness, and freckles which is neither positive nor negative but simply shows that change is constantly occurring in the human genome.

Use your model and the information above to answer the following questions

1. Identify different genes and the role they play in determining human eye color.
2. Explain why the genetics of human eye color is so difficult to determine.
3. Create a flow chart starting with DNA that illustrates the role of these genes in producing blue eye color.
4. Using the information provided about human eye color in the scenario and the model you created as evidence; defend the statement that mutations can be neither detrimental nor beneficial.
5. Hypothesize other unique effect that additional mutations occurring in the *HERC2* gene might have on the expression of eye color.

APPENDIX N

APPLICATION #5B PROBABILITY AND INHERITANCE

Biology

Probability and Inheritance

Application #5B

In 1866 Gregor Mendel, an Austrian Monk, published the results of his study of inheritance in garden peas. Although Mendel did not understand the mechanisms of inheritance, his work became the basis for the modern study of genetics. From his studies on the inheritance of certain traits in pea plants, Mendel formulated three laws of inheritance: the Law of Dominance and Recessiveness, the Law of Segregation, and the Law of Independent Assortment.

Mendel thought that every trait was controlled by a pair of factors, which we now call genes. The Law of Domiance and Recessiveness states that one gene, the dominant allele, prevents the appearance of the phenotype controlled by the other gene, the recessive allele. The Law of Segregation states that during gamete (egg and sperm) formation, the pair of genes for a trait separate, so that each gamete contains only one of the genes for the trait. The Law of Independent Assortment states that as the gametes are being formed, the genes for various traits separate independently of one another.

In this activity, you will learn to calculate probabilities for events. You will then use your skills in calculating probabilities to predict the inheritance of specific genetic traits in peas.

Objectives:

During this investigation, you will

1. Predict the probability of the occurrence of a single event
2. Predict the probability of two independent events occurring at the same time
3. Apply Mendel's principles to predict the occurrence of certain traits in the offspring of parents exhibiting particular traits.

Equipment:

Two 10-sided Dice of different colors
Two pennies
Masking tape
Sharpie marking pens

Application

Part I: Occurrence of a Single Event

1. Sitting on your table you will find two dice of different colors. Note that each dice has 10 sides (examine the dice carefully to clearly identify the difference between the numbers 6 and 9, and note that 0 represents the number 10). Roll the dice to examine how they roll. Note the number rolled is the number which appears at the top when the dice has stopped rolling.

   a. Select one number from your dice, record that number here: _____.

   b. Probability is typically stated as a fraction where probability = the number of one type of event/the total number of possible events. Determine the probability of rolling the number you selected on the dice at your table (show the probability as a ratio). Write the probability here: __________.

2. Choose a single dice and roll it 40 times. Have your partner count how many times the dice lands on the number you selected and how many times it lands on the other numbers (record the results under the Observed row for 40 rolls in Table I.

Table I: Probability of the Occurrence of a Single Event											
		1	2	3	4	5	6	7	8	9	10
40 Rolls	Observed										
	Expected										
	Deviation										
60 Rolls	Observed										
	Expected										
	Deviation										
Total Rolls	Observed										
	Expected										
	Deviation										

a. Use the law of probability to determine how many times out of 40 rolls you would expect the selected number to appear and how many times you expect each of the other numbers to appear (record your answers in the Expected row for 40 rolls in Table I).

3. Calculate deviation by subtracting the expected number from the observed number. Record these in the Deviation row for all 40 rolls in Table I. Record all probabilities as a positive number.
4. Now have your partner repeat steps 1 and 2, but roll the dice 60 times. Keep track of how many times the dice lands on the number your partner selected and how many times it lands on each of the other numbers.

a. Record the selected number here: _____

b. Record the observed numbers in the Observed row for 60 rolls in Table I.

c. Calculate the probability of rolling the number your partner selected, as well as the probability of rolling each other number. Record your answers in the Expected row for 60 rolls in Table I.

d. Add the observed numbers of the selected number and for each of the other numbers from the two trials and record the totals in the Total rows in Table I. Then calculate the deviations and record these numbers.

Part II: Independent Events Occurring Simultaneously

1. In this portion of the application you will roll both dice simultaneously 10 times. Designate one of your two dice to be the first number and one to be the second number. Have your partner keep track of each combination of numbers as it appears.

a. Record the numbers in the Numbers column of Table 2 and then record the number of times that combination appeared in the Observed column.

b. Calculate the percent of the total that each number occurred and record it in the proper column. To find the percent, divide each observed number by 10 and multiply by 100.

According to law of probability, when there are equally likely outcomes from a procedure, the probability that one of the outcomes will occur is 1 over the number of events (in this case 1/100 or 1%). We can see how this calculated. For example, we know that in rolling one dice, the probability of a particular number coming up is 1 in 10 or 10%. The probability of the same number appearing on the other dice is also 1 in 10 or 10%. The probability of the same number appearing on both dice in one toss is 1/10 x 1/10 = 1/100 or 1%.

2. Using the law of probability, predicted the expected outcomes of rolling both dice.
   a. Record the expected numbers in the proper column in Table II.
   b. Calculate the percent of the total that each combination is expected to occur, as you did above (problem 1-b). Enter these numbers in the proper column.
   c. Calculate the deviation by subtracting the expected from the observed and enter your results in Table II.

Table II: Probability of the Occurrence of a Single Event

Number	Observed	%	Expected	%	Deviation
Total	**10**	**100%**	**10**	**100%**	

Part III: Probability and Mendelian Genetics

We can use the law of probability to predict the probability of given genetic traits appearing in the offspring of particular parents. Punnett squares can also be used to make these predictions.

When gametes are formed, the pair of genes that determine a particular trait separate, and one gene goes to each gamete. When fertilization occurs, a male and female gamete fuse. The resulting zygote which developes into the new individual, now contains two genes for the trait. Which two of the parents genes appear in the zygote is a result of chance.

In this case we will consider the inheritance in pea plants of round and wrinkled peas. R will represent the dominant gene for round peas and r will represent the recessive gene for wrinkled peas.

1. Put a small piece of masking tape on each side of two pennies. On one penny write R on each side. On the other penny write r on each side.
2. Toss the pennies several times
   a. What combinations of genes always appear?

   b. Would the offspring with these two genes be round or wrinkled?

   c. Are the offspring considered purebreds or hybrids?

3. Replace the old tape with new tape. On each penny write R on one side and r on the other side. Toss the coins simultaneously until all possible combinations of genes have appeared.
   a. What combinations of genes appear?
   b. For each of the combinations, would the offspring be round or wrinkled? Purebred or hybrid?

Post Application

Analysis

1. In part I, what was the expected ratio of your chosen number to all other numbers for rolls of a single die? Did your results always agree with the expected ratio? If not, what would be an explanation for the deviation?

2. Compare the deviations from the expected for 40 and 60 rolls. What seems to be the relationship between sample size and deviations?

3. In Part II, what was the probability that a particular number would appear? Show your calculations.

4. If you rolled both dice simultaneously 400 times, would you expect the deviation to be greater or less than it was in rolling them 40 times?

5. In Part III, when an RR plant was crossed with an rr plant, would the offspring have round or wrinkled peas?

6. Which of Mendel's principles did you apply in order to answer question #5.

7. What is the probability of rolling the 10-sided dice ten times and getting #3 every time (show all calculations)?

6. What is the probability of rolling the ten-sided dice 20 times and getting the number "5" 20 times in a row (show your calculations)?

Conclusion

On a separate sheet of scrap paper, using the application objectives and evidence draw from the activity, write out the answer the following; who, did what, to whom or what, when, where, how, and why. Then here in the lab, using formal writing style, in your own words, write a single paragraph that describes what you learned by combining the answers you gave to the following; who, did what, to whom or what, when, where, how, and why. Start with the statement, **"By performing this lab experiment I . . ."**

Reference: Adopted from

Bjork, W.B., Horn, R.D, Schraer, W.D., and Stoltze H. J. (1991). *Laboratory Manual: Biology, the study of life.* Needham, Massachusetts: Prentice Hall.

APPENDIX O

PREUNIT GENETIC PRINCIPLES TARGET ASSESSMENT

Preunit Genetics Principles Target Assessment

Larger than hamsters, but smaller than rabbits, guinea pigs, also known as cavy, can weigh a couple of pounds and generally live for five to seven years. The guinea pig is a species of rodent belonging to the genus *Cavia*. Despite their common name, they are not pigs, nor are they from Guinea. How and why they came to be called “pigs” is not clear. They do not exist as a species in the wild.

The guinea pig has enjoyed widespread popularity as a household pet since its introduction by European traders in the 16th century. Their docile nature, acceptance of handling and relative ease of care continues to make them a popular pet. They only rarely bite. Guinea pigs are social animals that prefer to live in small groups. The male guinea pig is referred to as a boar; females are sows, and their young (in a break with the preceding porcine nomenclature) are called pups.

Biological experimentation on guinea pigs has been widespread since the 17th century, and their frequent use in scientific research has resulted in the widespread use of the term “guinea pig” to refer to a test subject.

Coat color in guinea pigs consists of ten different coat color patterns; the self pattern consists of a single solid color such a tan, black, or white. Dutch consists of a head of the same color as the hind end, with a white blaze and the front half of the body is white, while brindle consists of one dark color and white intermingled over the entire body. Tortiseshell consists of well-defined black and red patches of color uniformly distributed across the body, and tortiseshell and white consists of well-defined black, red, and white patches of color divided along the midline of the back. Roan consists of white and darker hairs mixed evenly over the entire body, while himalayan consists of a white body with a black or brown nose. Agounti consists of hairs with alternating dark and light bands of color, albino is the complete absence of pigmentation and dalmation consists of a white body with dark spots.

Laura owns several Self-colored guinea pigs, and decides to breed a male and female which are both black. The cross produces a litter consisting of three black and one white female pups. When the white female matures, she is mated with a black male and produces eight pups, all of which are black.

1. Identify the alleles that are present in the example problem, and the different role they play in determining guinea pig coat color.
2. Identify the allele types found in the original black guinea pigs described in the example problem.
3. Create a Punnet square model showing the original parental cross of black guinea pigs, which illustrates the inheritance of the alleles resulting in the coat colors in the first litter.
4. Using the information provided about guinea pigs in the scenario and Punnett square models as evidence; defend the statement that white coat color in guinea pigs is the result of a recessive allele.
5. Hypothesize the probability of coat colors that would result if two pups from the litter of the black and white parents were crossed.

APPENDIX P

EXAMPLE CHALLENGE PROBLEM

Example Challenge Problem

Curly hair in guinea pigs is caused by a gene whose effect is recessive to that for straight hair. (a) If 96 guinea pigs where raised from a cross between individuals that were heterozygous for this gene, how many would be expected to be curly haired and how many would be straight haired? (b) If you had a straight haired guinea pig, what would be the easiest way to determine whether it is homozygous or heterozygous?

APPENDIX Q

FINAL CHALLENGE PROBLEM

Final Challenge Problem

This final challenge problem provided students with a genetics challenge problem regarding a situation in which one rancher (the plaintiff) claims another (the defendant) cut a fence to allow his bull to bred with the defendant's cows. The defendant counter claims that he used sperm from a well-known sperm bank to artificially inseminate (A.I.) his cows. Individual students will be assigned the task of representing each of the respective ranchers and an arbitrator, and the remaining students will be divided up randomly into the prosecuting and defense team attorneys. Each "rancher" will be provided a background sheet of information which they can provide to their team of attorneys. Teams will be given two class periods and access to the internet to research and prepare their case. Each team will then be required to use evidence to effectively argue their claim before the arbitrator in 15 minutes and the opposing team will be given 5 minutes to provide a rebuttal to the claim. The following day, the arbitrator will render a decision regarding the initial claim and provide their evidentiary reasoning for the verdict.

Background Information for the Arbitrator

You have been chosen to preside over the arbitration of a case in which Harold Hobbyfarm (the plaintiff) claims that Levi Lotsofcows cut a fence to allow Harold's bull to breed with his cows. Levi's counterclaim states that he used sperm from a well-known sperm bank to artificially inseminate (A.I.) his cows.

Each team will then be required to use evidence to effectively argue their claim before you in 15 minutes, and the opposing team will then be given 5 minutes to provide a rebuttal to the claim. The following day, you will render a decision regarding the initial claim and provide your evidentiary reasoning for the verdict. The Plaintiff's team will present first, followed by the Defendant's team.

Background Information for Harold Hobbyfarm

You own a small hobby ranch of high-end purebred Black Angus Cattle. Your certified bull, Zoro is a son of BSAR Opportunity of Bovine-elite. While you have a lot of money, you could buy Levi's place ten times over and never notice, you don't look the part. You are usually dressed in well-worn, stained bib overhauls or jeans with suspenders and a tattered button shirt, and you always wear a sweat-stained straw hat. You drive a beat up pick-up truck. Your love is your purebred Black Angus bull, Zoro.

In late February, You discovered that the fence-line between your bull pasture and Levi's cow pasture was down, and Zoro was in the cow pasture. A close inspection of the wire however reviled that it had been cut. You called the Sheriff out and filled a complaint against Levi, claiming that Levi had deliberately cut the fence to allow Zoro access to his fertile cows in an effort to up his calf crop. Unfortunately the Sheriff's department was unable to obtain any physical evidence linking Levi to the cutting of the wire.

You have filed suit against Levi, claiming that Levi owes you for the unauthorized use of your bull to sire calves. You value breeding fees for Zoro at $100/cross.

You have hired the best team of attorney's that money can buy.

The case has been remanded to arbitration and an arbitrator, Stan Finaldecision, has been chosen to preside over the arbitration.

http://www.vgl.ucdavis.edu/services/coatcolorcattle.php

http://homepage.usask.ca/~schmutz/polled.html

http://www.bovine-elite.com/angus.asp

http://en.wikipedia.org/wiki/Frozen_bovine_semen
http://www.bova-tech.com/faq.html

Background Information for Harold's Attorneys

Your team has been hired to represent Harold Hobbyfarm. Harold has accused Levi of cutting a fence to allow his bull, Zoro access to Levi's cows. Levi claims that he had nothing to do with the cut wire, and that all his calves are either the product of Artificial Insemination (A.I.) with frozen Bovine sperm that he purchased or the result of early breeding with a Red Angus Bull that passed away in early winter.

The case has been remanded to arbitration and an arbitrator Stan Finaldecision has been chosen to preside over the arbitration.

As the representative of the Plaintiff, you will be presenting your case first. Your team will be given 15 minutes to effectively argue your client's claim before the arbitrator, and the opposing team will then be given 5 minutes to provide a rebuttal to your evidence. They will then have 15 minutes to argue their client's claim and you will be given 5 minutes to provide a rebuttal to their evidence. The following links may provide some useful background information;

http://www.vgl.ucdavis.edu/services/coatcolorcattle.php

http://homepage.usask.ca/~schmutz/polled.html

http://www.bovine-elite.com/angus.asp

http://en.wikipedia.org/wiki/Frozen_bovine_semen

http://www.bova-tech.com/faq.html

Background Information Sheet for Levi Lotsofcows

You own a large ranch of mixed Angus cattle, and you like to look the part of a wealthy cattle rancher. You frequently spend lots of money on new pick-ups and fancy clothes, which has a tendency to leave you in a poor cash flow situation. Your old Red Angus bull, Vardo, passed away last winter. Realizing that the few crosses that had previously occurred between Vardo and some of your cows would not provide sufficient calves to cover your overdue bills, you came up with a desperate plan to cut the fence between you and your neighbor Harold to allow Harold's bull Zoro access to your cows. To cover your tracks, you spent $3,600 with Bovine-elite for frozen Black Angus semen. Your cash crop for the year consists of 200 calves, 180 black Hereford calves and 20 red Angus calves. You purchased the semen of Bon View New Design 878 @ $18.00 a straw.

While you did indeed cut the fence to allow Zoro to breed your cows to increase your calf crop, you claim that you had nothing to do with the cut wire, and that all your calves are either the product of Artificial Insemination (A.I.) with the frozen Bovine sperm that you purchased or the result of an early breeding with Vardo.

You have hired the best team of lawyers you could afford to defend yourself. How much information beyond the basics of the case you choose to share with your lawyers is up to you.

The case has been remanded to arbitration and an arbitrator Stan Finaldecision has been chosen to preside over the arbitration.

The following links may provide some useful background information;

http://www.vgl.ucdavis.edu/services/coatcolorcattle.php

http://homepage.usask.ca/~schmutz/polled.html

http://www.bovine-elite.com/angus.asp

http://en.wikipedia.org/wiki/Frozen_bovine_semen

http://www.bova-tech.com/faq.html

Background Information for Levi's Lawyers

Your team has been hired to defend Levi Lotsofcows. Levi has been accused of cutting a fence to allow his neighbors bull access to his cows. Levi claims that he had nothing to do with the cut wire, and that all his calves are either the product of Artificial Insemination (A.I.) with frozen Bovine sperm that he purchased or the result of early breeding with a Red Angus Bull that passed away in early winter.

The case has been remanded to arbitration and an arbitrator Stan Finaldecision has been chosen to preside over the arbitration.

As the representative of the Defendant, you will be presenting your case last. The Plaintiff's team will be given 15 minutes to effectively argue their client's claim before the arbitrator, and you will then be given 5 minutes to provide a rebuttal to their evidence. You will then have 15 minutes to argue your client's claim before the arbitrator and they will be given 5 minutes to provide a rebuttal to your evidence. The following links may provide some useful background information, and you are welcome to find more;

http://www.vgl.ucdavis.edu/services/coatcolorcattle.php

http://homepage.usask.ca/~schmutz/polled.html

http://www.bovine-elite.com/angus.asp

http://en.wikipedia.org/wiki/Frozen_bovine_semen

http://www.bova-tech.com/faq.html

APPENDIX R

POSTUNIT GENETIC PRINCIPLES TARGET ASSESSMENT

Postunit Genetic Principles Target Assessment

Texas Longhorns are a breed of cattle known for their characteristic horns which have spans from tip to tip of up to 7 feet in steers. They are a hybrid breed resulting from the random mixing of Spanish *retinto* (criollo) stock and English cattle.

Early Spanish settlers brought cattle to New World near the end of the 17th century; these cattle escaped or were turned loose on the open range, where they went feral. Over several generations, descendants of these cattle evolved into a tough, rangy animal with long legs and long horns and the high feed and drought stress tolerance longhorns are known for. These feral Spanish cattle mixed with the Anglo cattle and by the event of the Civil War, Texas Longhorns emerged as a recognizable breed. Although the breeding to eastern cattle had little effect on the make-up of a Longhorn, it did alter coat color patterns.

Criollo cattle are a solid color ranging from Jersey tan to cherry red; black animals are few and brindles rare. Longhorns are known for diverse coloration, varieties include roans, brindles, speckled patterns, linebacks, grullas, reds, yellows oranges, browns and blacks, although dark red and white mixes are most common. Surprisingly, just two pigments produce all these hair colors in cattle (and in fact all mammals). These two pigments are eumelanin (black) and phaeomelanin (red); Eumelanin is a black pigment that can look brown in lower concentrations and Phaemelanin is a red pigment that can look orange or yellow in lower concentrations. If neither pigment is produced, hair is white. Therefore all the variations come from varying amounts and patterns of the expression of these two pigments on different parts of the body. However, the distribution of these two pigments is controlled by a large number of different genes which makes the inheritance of the two pigments somewhat complex.

Modern hobby breeders of Texas Longhorns have become quite common and Longhorns with elite genetics can often fetch $40,000 or more at auction. The record is $170,000 in recent history for a single cow.

A black Longhorn nonbrindle bull breeds with a wild type Longhorn brindle cow; wild type coat color exhibits both black and red pigments and brindling causes alternating stripes of black and reddish brown. The resulting bull calf is nonbrindled and red.

1. Identify the alleles that are present in the example problem, and the different role they play in determining Longhorn coat color.
2. Identify the allele types found in the original Longhorn cattle described in the example problem.
3. Create a Punnet square model showing the parental cross of a black Longhorn brindle bull with a wildtype brindled cow, which illustrates the inheritance of the alleles resulting in the coat color of the calf.
4. Using the information provided about Longhorn cattle in the scenarioyou're your Punnett square model as evidence; defend the statement that brindled coat color in Longhorn coat color is the result of a dominant allele.
5. Hypothesize the probability of coat colors that would result if the bull calf from this cross were crossed with a wild type brindle cow.

APPENDIX S

PRE AND POSTUNIT STUDENT CONCEPT INTERVIEW

Pre and Postunit Student Concept Interview

Please complete this interview honestly. Participation is voluntary and will not affect your grade. There are no wrong or right answers, but your answers will help me in becoming a better instructor for you. Please be straight forward and detailed with your responses.

Questions will apply to the following concepts as appropriate;

Nonintervention unit: Bacteria's role in our world
Intervention unit #1: How DNA is involved in determining heredity
Intervention unit #2: Mendelian genetics and how genes determine inheritance

1: Not at all *2: Very Little* *3: Somewhat* *4: Generally* *5: Lots*

Rank your choice for each item using the scale I have given you.

1. I feel/felt confident in my understanding of [appropriate topic]. 1 2 3 4 5

2. I feel/felt motivated to learn about [appropriate topic]. 1 2 3 4 5

3. I feel/felt confident in my ability to use math, models and supporting evidence to explain biological concepts. 1 2 3 4 5

4. I feel/felt that designing diagrams and/or models help me with understanding [appropriate topic]. 1 2 3 4 5

5. I feel/felt that having to defend my position with evidence helped me with understanding [appropriate topic]. 1 2 3 4 5

For those you answered of #1-#5 above with a 1, 2, or 3, please explain in detail.

I would like you to create a diagram or model using the materials provided: poster paper and cards with vocabulary words and terms.

Your starting point will be [determined by topic: NT; bacteria, T#1; a cell, and T#2; a 8x8 punnett square]. Arrange the materials on the poster paper to your liking, showing how the concepts and terms are interrelated. Once you are comfortable with how you have arranged the post-its, you may choose to add blank post-its to your diagram or model containing additional words or terms that were not included. Once you finish, add linking words or phrases by writing on the poster paper to show how all the concepts are related.

Nonintervention Unit: antibiotics, decomposing, denitrifying, disease, digestion, genetic engineering, nitrifying, nitrogen fixing, photosynthesis, and respiration.
Intervention Unit #1: asexual reproduction, genetic engineering, meiosis, molecular Composition of nucleic acids, mutation, protein synthesis, replication, sexual reproduction, transcription, and translation.
Intervention Unit #2: Use our “gotta-have” checklist, a punnet square and probability

Then you will use your diagram or model to answer the following questions related to the unit of study:

Nonintervention Unit: Since bacteria causes’ disease and sickness, many people wish to eradicate all bacteria from themselves and the world. Use your diagram and knowledge from this unit as evidence to explain why this is not only impossible to accomplish, but also a very poor idea.
Intervention Unit #1: Lee suffers from a rare genetic situation which causes his eyes to be of two different colors, one blue and one brown. Use your model and knowledge from this unit as evidence to explain how this is possible.
Intervention Unit #2: You have a female wolf that is white with blue eyes. Your male wolf is black with brown eyes. Your female went into heat and bred, and you assumed it was with your male. However, she birthed only a single white pup with blue eyes. Use a punnett square and your knowledge from this unit to show how this outcome is possible and calculate what the probability is of getting a white pup with blue eyes.

6. [Postunit Only] What activity/activities was/were most helpful in helping you to understand [appropriate topic]. Please explain why.

7. [Postunit Only] What activity/activities was/were least helpful in helping you to understand [appropriate topic]. Please explain why.

8. [Postunit Only] What activity or instruction needs to be improved or changed to help you understand [appropriate topic]. Please explain how you think these should be changed and how the changes will help you learn.

APPENDIX T

CONCEPT MAP SCORING RUBRIC

Concept Map Scoring Rubric

Map Components	Possible Points	Awarded Points	Special Things Noticed About Map
Main Idea [Set-up]			
Clear and meaningful to [Bacteria] [Molecular Genetics] [Principles of Genetics: Identified Alleles]	2 each		
Used additional appropriate terms [Parental alleles and cross set-up correctly]	3 each		
Terms appropriately linked [Gametes correctly identified]	2 each		
Terms vaguely linked [N/A]	1 each		
Branches [Punnett Square]			
Linked to central idea [Appropriately sized]	1		
Grouping of connected ideas (branching) [Parents appropriately placed]	3 each		
Terms organized from general to specific [Correctly identified phenotype of offspring]	5 each level		
Links established between branches [Correctly use ratios to answer question]	10 each		
Total			
Overall reaction to map and special things noticed			

References Adopted from

Novak, J.D. & Gowin, D.B. (1984). *Learning how to learn.* New York, NY: Cambridge University Press

APPENDIX U

INSTRUCTOR FIELD NOTE PROMPTS

Instructor Field Note Prompts

It is not necessary for the instructor to answer every prompt daily, nor to give an explanation for each. However, it is encouraged to answer all that apply and explain as much as possible.

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

Rank your choice for each item using the scale I have given you.

1. My attitude today was positive SD D N A SA
   Explain

2. How did my attitude affect my students' learning?

3. What shaped my attitude today?

4. I was motivated to teach today SD D N A SA
   Explain

5. How did my motivation affect my students' learning?

6. What motivated me to teach today?

7. Today's activities empowered the students to learn.

   Explain SD D N A SA

8. What improvements could I make in the lesson?

9. What is my plan for tomorrow?

Student engagement/motivation and instructor engagement/motivation were rated daily based on a 5 point scale with 1 being least motivated and 5 being most motivated. Overall student engagement/motivation and instructor engagement/motivation was awarded by averaging the scores. Additional comments on specific lesson effectiveness were also noted.

Student	Student Engagement/Motivation		Instructor Engagement/Motivation	
	Score	Notes	Score	Notes
Insert student names (1 per line)				
Overall Scores				
Was this activity/lesson effective/not effective with student content understanding and motivation? Why was it effective or not effective? How might it be changed to make it more effective?				

APPENDIX V

PRE AND POSTINTERVENTION NONCONCEPT STUDENT INTERVIEW

Pre and Postintervention Nonconcept Student Interview

Please complete this interview honestly. Participation is voluntary and will not affect your grade. There are no wrong or right answers, but your answers will help me in becoming a better instructor for you. Please be straight forward and detailed with your responses.

1. Which activities did you find the most interesting? The least interesting? Please Explain.

2. Which activities do you think actually helped you to understand the unit the best? Explain.

3. What was your favorite activity in this unit? Why?

4. If you were in charge of teaching the next unit, what sort of activities would you like to use during class time? What about during class time?

5. Is there anything else I should have asked? If so please state and answer the question.

6. [Postintervention Only] Did you like using math, designing models, and providing supporting evidence? Yes or No. Please explain with example(s).

7. [Postintervention Only] Do you think using math, designing models and providing supporting evidence affected your higher order thinking skills? Yes or No. Please explain with example(s).

APPENDIX W

PRE AND POSTINTERVENTION INSTRUCTOR ENGAGEMENT/MOTIVATION SURVEY

Pre and Postintervention Instructor Engagement/Motivation Survey

It is not necessary for the instructor to answer every prompt daily, nor to give an explanation for each. However, it is encouraged to answer all that apply and explain as much as possible.

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

Rank your choice for each item using the scale I have given you.

1. I am confident in my teaching abilities. SD D N A SA
   Explain

2. I enjoyed teaching my students. SD D N A SA
   Explain

3. I felt motivated to come to school each day. SD D N A SA
   Explain

4. I have a positive attitude towards using the selected NGSS practices.
   Explain SD D N A SA

5. My motivation is driving me to become a better instructor.
   Explain SD D N A SA

6. My engagement/motivation contributes to the engagement/motivation of my students. SD D N A SA
   Explain

7. What is my motivation to teach? How does my motivation affect my teaching and the learning of my students? Explain

8. What is contributing to my attitude toward teaching? How does my attitude affect my teaching and the engagement/motivation of my students? Explain.

APPENDIX X

NONINTERVENTION AND INTERVENTION COLLEAGUE OBSERVATIONS

Nonintervention and Intervention Colleague Observation

The following are prompts for colleague observations during the nonintervention and intervention units. An explanation with each prompt is not always necessary, but is encouraged, and the colleague is not limited to the list below

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

Rank your choice for each item using the scale I have given you.

1. Instructor shows motivation for teaching. SD D N A SA
   Explain.

   How does this affect the students?

2. Students are engaged in the lesson. SD D N A SA
   Explain.

3. Students are demonstrating motivation to learn new materials.
   SD D N A SA
   Explain.

   What seems to motivate students? What does not?

4. Student/instructor interaction was positive and conducive to learning.
   Explain. SD D N A SA

5. How does the motivation of the instructor change with the motivation of the students? Explain.

6. Where could you see improvements in the instructors’ engagement or motivation?

7. What could be improved about this class? Explain.

APPENDIX Y

WEEKLY INSTRUCTOR REFLECTIVE JOURNAL PROMPTS

Weekly Instructor Reflective Journal Prompts

It is not necessary for the instructor to answer every prompt daily, nor to give an explanation for each. However, it is encouraged to answer all that apply and explain as much as possible.

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

Rank your choice for each item using the scale I have given you.

1. Students were excited about class this week. SD D N A SA
   Explain

2. Students were enthusiastic participants in class this week. SD D N A SA
   Explain

3. What did students complain about this week? Explain.

4. What positive comments did students make this week? Explain.

5. What area of content and application did students seem to have a good understanding of? Explain.

6. What area of content and application did students seem to struggle with, and why did they struggle?

7. What activities and lessons seemed to be effective in motivating students and helping them understand content? Why were these effective?

8. What activities and lessons were not effective in motivation students and helping them understand content? What could I do in the future to improve these activities/lessons?

9. Did the selected NGSS practices seem to empower students in understanding and applying content? Why?

10. What was the most satisfying aspect of class this week? Explain?

11. What was the most frustrating aspect of class this week? Explain?

12. How did students react to the teaching style (traditional vs. NGSS) this week? Explain?