THE EFFECTS OF PROBLEM-SOLVING CASE STUDIES ON UNDERSTANDING HIGH SCHOOL BIOLOGY

by

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STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master’s degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

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ABSTRACT

The purpose of this project was to study the effects of problem-solving scenarios in biology as a learning strategy for high school biology students. Students were exposed to a variety of problem-solving scenario activities including video, written, and hands-on activities that related biology content to real-world applications. The project began with a nontreatment unit on DNA structure and function where students were engaged in traditional biology learning activities that included reading, lecture, video, labs, and hands-on simulations. Students were then exposed to two treatment units, one on gene expression and mutation and the other on natural selection. During both treatment units students engaged in a variety of problem-solving scenarios for the purpose of connecting biology content to real-world applications with the hope of improving student understanding and motivation. Scenarios included video, reading, and simulation case studies on a variety of topics. Data were collected using student preunit and postunit assessments, surveys, and interviews with concept mapping as a measure of student content understanding, higher-order thinking, and motivation. In addition, teacher data were collected using classroom observations and teacher reflections to gain understanding of student motivation, as well as, teacher motivation and pedagogy. The data showed improvement of student understanding and motivation, especially when a combination of problem-solving case studies included hands-on scenarios activities.

INTRODUCTION AND BACKGROUND

In my experience as a science educator, I have been exposed to and used a variety of teaching strategies for the purpose of improving student learning in my classroom. As a reflective practitioner, I have developed common themes and goals in science education. My primary desire is for students to understand important science concepts and processes, and then be able to apply their science understanding in a variety of real-world situations using higher-order and critical thinking skills. With this foundational belief, I have embarked upon a great deal of reflection in my own teaching practices. Most notably, while taking courses in the Masters of Science in Science Education (MSSE) program through Montana State University, I found problem-solving case studies embedded in both ecological and human biology content enhanced my own learning and led me to higher levels of conceptual understanding and application of knowledge. Problem-solving case studies are real-world and/or fictional scenarios that are used by educators to engage students in content and process information, or more simply stated, using stories to portray an educational message (Herreid, 2007). Specifically, I found the experience of looking at challenging problems through case-based learning where information was given in a real-world scenario, followed by Socratic questioning and thought-provoking clues, was highly engaging and effective for my own learning and motivation. This personal insight has challenged me to apply this learning model to my own classroom and give my students the opportunity to work with real-world scenarios in a cooperative setting for the purpose of improving science content and process understanding.

Beyond my own learning experiences, I have found a gap between my desire for students to reach higher-order thinking and the learning opportunities I provide in my classroom. We, as teachers, often set high goals and want our students to connect ideas with great depth; however, through my own observation and reflection, I have found that students need scaffolding and guidance in inquiry-based classroom models to reach the higher levels of cognition, such as the levels of analysis and evaluation in Bloom's Taxonomy. Therefore, my goal was to allow students to learn, use, and apply science concepts and processes through meaningful real-world problem-solving case studies embedded in science content with the hope that this intervention would provide the necessary scaffolding to build students up to higher levels of understanding science concepts and processes.

Beyond my personal reflection, I have observed that most high school students are interested in the social-emotional aspects of life, with side conversations often centered on peer interactions and the impact of behaviors on others; therefore, by using problem-solving scenarios my hope was to appeal to the innate student desire to connect with real-world scenarios that involve people and nature in an effort to help them learn. In my personal opinion, the scientific community would benefit greatly by placing more content in context; hence, we cannot have science without a connection to humanity. Furthermore, from my personal experience in the high school science classroom, student engagement and motivation are one of the most important criteria in the learning environment, and higher levels of both likely lead students to take more science courses or possibly pursue future careers in science. Therefore, the goal of capturing and maintaining student excitement and enthusiasm for learning is a key component and a major reason active-learning strategies are used in the science classroom. As an active-learning strategy, problem-solving case studies challenge students to use and apply their understanding of science content and process skills.

Overall, the development of my capstone project area of focus was determined by my observation, experience, and reflective practice over six years of teaching science in both public and private education. My desire to shift towards problem-solving scenarios embedded in science content was in large part due to a change in my own pedagogy as a direct result of using such strategies during coursework with me in the role of learner. Moreover, I was interested to learn the effect such interventions would have on student learning, higher-order thinking, and motivation in my own biology classroom. Therefore, the focus question for this capstone project is, what are the effects of problem-solving case studies on student understanding of high school biology concepts? The subquestions for this project are as follows: what are the effects of problem-solving case studies on student higher-order thinking in high school biology; what are the effects of problem-solving case studies on student motivation in high school biology; and what are the effects of problem-solving case studies on teacher motivation and pedagogy in high school biology?

This capstone project was conducted with 36 tenth-grade high school students in my biology classes at Ferris High School in Spokane, Washington. Students in my biology classes are a mix of general education students, with few students requiring individualized education plans.

My committee members for this capstone were Jewel Reuter, as project advisor, and Shannon Walden, as project reader. Jewel and Shannon are both MSU faculty members and teach courses in the MSSE program. In addition, Robin Tillman, another MSSE graduate student, served as support team members. Furthermore, Christine Ryman, a former history and humanities teacher now working at Gonzaga University served as a support team member. Christine has a history of creating relevance in her content area and is a master teacher.

CONCEPTUAL FRAMEWORK

The following conceptual framework includes evidence of the impact found in literature reviewed for case-based methods of teaching. First, I will explain problem-solving case studies in the science classroom; followed by the effects of other case-based teaching practices on student understanding of science concepts and higher-order thinking. Next, I will explain the positive impact problem-solving case studies have had on student motivation. Finally, I will share insight from educational practitioners on how case-based teaching strategies have motivated teachers and shifted pedagogy in science education.

Teaching methods using problem-solving scenarios have been given a variety of titles, such as problem-based and case-based learning; yet the underlying tone to each is learning opportunities that are relevant, realistic, engaging, challenging, and instructional (Kim, Phillips, Pinsky, Brock, Phillips, & Keary 2006). The idea behind this learning model is to allow students to apply content and process knowledge in a way that they become directly invested and involved in the process of solving problems, and in so doing develop the higher-order and critical thinking skills necessary to maintain ingenuity in America. As a leading author on case method teaching, Herreid (2007) simply states "a case study is a story with an educational message" (p. 27). Furthermore, in his compilation of journal articles and literature review, Herreid cited three basic types of educational cases from Reynolds' 1980 work. Herreid's general analysis is that educational case studies, such as decision/dilemma appraisal, that employ the use of realistic problem-solving scenarios seem to be most effective in the classroom.

Educational case studies are used and becoming increasingly prevelent in many professional preperation programs. In fact, many business and law schools use case study methods of teaching students. Harvard University was one of the pioneers of using such methods in their educational programs, such as law and business, and Professor James Conant may be one of the first to use such case-based teaching methods in science with his chemistry courses at Harvard (Herreid, 2007). We now see a broader use of educational case studies used throughout the fields of science; the medical and engineering fields use problem-solving case-based learning strategies to train professionals to apply content knowledge to real life challenges (Kim et al., 2006). Most case method teaching has been conducted at the college level, with an increase in case studies as a teaching tool; yet my hope is see how such teaching strategies would affect student understanding in high school biology.

The use of problem-solving case studies as an instructional method has been shown to have positive impacts on student understaning of science concepts, as well as higher-order thinking. Yadav, Lundeberg, Deshryver, Dirkin, Schiller, Maier, K., & Herreid (2007) surveyed 101 university and college instructors in the United States and Canada and found instructors who had received professional development and implemented case-based strategies felt such instructional tools had a positive effect on student learning, critical thinking, and participation. Furthermore, more quantitative analysis in both Chaplin (2009) and Rybarczyk, Baines, McVey, Thompson, and Wilkins (2007) studies found significant improvement in undergraduate students' understanding of science concepts following instruction that implemented problem-solving case studies. While Chaplin found continued improvement throughout the general undergraduate biology course compared with students not exposed to case-based strategies, Rybarczyk et al. found students developed higher-order thinking skills and were more likely to answer misconception questions correctly with cellular respiration concepts.

The reason for the success of educational case studies on student understanding and higher-order thinking is likely due to our human connection to stories. In the development of educational case studies, the realistic scenario builds context for understanding science concepts, a "reason" for students to learn science. Even more, the goal of problem-solving case studies is more than just to understand a concept, but to use conceptual understanding to solve a problem, evaluate scenarios, make decisions, and understand the process of science with people in mind (Herreid, 2007). It is the science-human connection I wanted to focus on with my work implementing case study scenarios in high school biology.

Undoubtedly, the real-world relevance of case studies motivates students to learn more. Yadav et al. (2007) noted instructor comments about student appreciation for real-world relevance and increased student participation, which is a measure of motivation. A study by Bowe, Voss, and Aretz (2009) showed that premedicine students positively received the case-based strategies, felt such strategies were preparing them for a future in medicine, and stated "the students found the experience empowering by honing their skills for self-directed learning" (p. 839). In possibly the most sincere form of flattery, studies at the State University of New York in Buffalo found case study courses resulted in 95% attendance compared with 50-65% attendance in general lecture courses (Herreid, 2007).

Many teachers would agree that when student learning is high and students are actively engaged in the process, teacher motivation increases. Specifically, Rybarczyk et al. (2007) found instructors who received professional development in case-based teaching methods and implemented case studies in their classroom realized benefits in student learning, and were willing to try case studies in other areas of curriculum, showing a pedagogical shift in instruction. Surveys of other teachers using problem-solving case studies also support favorable teacher reflection of case-based methods in the classroom (Yadav et al., 2007).

Overall, problem-solving case studies seem to have a highly positive impact of the science classroom. The evidence of increased student content knowledge, higher-order thinking skills, and motivation are all favorable; showing increased effectiveness in teacher pedagogy. Moreover, many teachers using case-based methods seemed to be motivated to use problem-solving strategies and were encouraged by the outcome of their students' performance in science. My hope in conducting this capstone project using interventions of problem-solving case studies in high school biology was to increase my own teacher effectiveness and see favorable student understanding, higher-order thinking, and motivation that will, in turn, result in more students pursuing future endeavors in the field of science.

METHODOLOGY

Project Treatment

This project was conducted over seven weeks, from January 25 through March 21 of 2011, and included one nontreatment unit on DNA and two treatments units. Treatment unit one was on gene expression and mutation, while treatment unit 2 was on natural selection. See Appendix A for project timeline. Preassessments and postassessments were administered for all instructional units and pre and postunit surveys were completed by students over each main topic to show connection of student understanding and motivation. The nontreatment unit included a variety of learning activities, while both treatment units emphasized cooperative learning through problem-solving scenarios mixed with various content learning activities. The purpose of embedded real-world scenarios was to increase student understanding by giving learning context (Herreid, 2007). The following outlines each unit.

Nontreatment Unit: DNA

The nontreatment unit covered the structure, function, discovery, and replication of DNA. Students began the unit with a preassessment and presurvey to check for prior knowledge and motivation. Students engaged in a variety of learning activities to gain knowledge about DNA. Formative assessment tools were used throughout the unit, and followed by a unit postassessment and postsurvey. A sample of six students, two each from high, medium, and low academic categories, constructed concept maps and were interviewed about their motivation and understanding of biology content. Teacher field notes, journal, and reflection were documented throughout the unit. See Appendix B for DNA lessons and materials.

Treatment Unit One: Gene Expression & Mutation

The first treatment unit covered protein function, protein synthesis, and mutation. The progression of student assessments, interviews, surveys, and teacher documentation, as mentioned above, remained consistent throughout all treatments. In treatment unit one, students were introduced to a real-world scenario of Georgi Markov's assassination in 1978 with the use of ricin. Students worked through the scenario in cooperative groups to answer questions based on the information they were given; excerpts from Secrets of the Dead online resources (Thirteen/WTEN, 2006). Following the initial problem scenario, students reviewed protein structure, learned about the function of enzymes, and designed and conducted an experiment testing factors affecting enzyme activity. Students returned to compare the Markov assassination throughout their learning experience, and following the enzyme lab, looked over additional information in the Markov investigation. Finally, students learned the process of protein synthesis, as well as, how and/or why genes are regulated, turned on and off. Once again, students returned to the Markov scenario and learned of the affects of ricin on ribosomes, ultimately disrupting the synthesis of all enzymes by affected ribosomes (Sadava, Heller, Orians, Purves, & Hillis, 2008). See Appendix C for protein function and synthesis lessons and materials.

Treatment unit 1 continued with stand-alone case study on Cystic Fibrosis, called "Sometimes it is All in the Genes," developed by Anne Galbraith and David Howard (2003) of the University of Wisconsin, as an introduction to genetic mutation. This stand-alone case study is written format that takes students though a progression of segments in a scenario, and is used independent of other content during the process, such that you could use a stand-alone case study at any given time and be able to use some aspect for students connecting content to real-life. Following the stand alone case study, students looked at an additional scenario about an albino deer found in nature (Campbell & Reece, 2008), learned about types and effects of genetic mutation, and then return to the albino deer scenario in an ethical dilemma about the protection or eradication of albino deer. See Appendix C for mutation lessons and materials.

Treatment Unit Two: Natural Selection

Treatment unit two consisted of three individual cases. It continued with the albino deer scenario, whereby, students look at shifting environmental conditions due to the emergence of the next ice-age as the mid-Atlantic current shuts down. Students were introduced to the likelihood of survivorship and differential fitness of deer in a new, whiter environment. Following the scenario, students were introduced to the concepts of natural selection and evolution, and then returned to the mini ice-age scenario that merges into an additional problem-solving case study about the next bubonic plague epidemic with cooling global temperatures. The bubonic plague epidemic scenario also related back to our genetics unit with heterozygous advantage individuals, having one copy of cystic fibrosis gene, having greater survival against bubonic plague. At the end of the natural selection unit, students engage in one more stand alone case study using a study by Lemons and Huber (2007) of Duke University, *Dr. Collins and the case of the mysterious infection,* which is a case study that looks at methicillin-resistant *Staphylococcus aureus* (MRSA) and antibiotic resistance. See Appendix D for natural selection lessons and materials.

Data Collection Instruments

This project used a variety of qualitative and quantitative data collection instruments in an effort to gain a holistic view of the effect of implementing problem-solving case studies in biology on student understanding of high school biology concepts. 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. Student data was collected from 36 sophomore students from three biology sections at Ferris High School in Spokane, Washington. Ferris is a public high school in Spokane Public Schools and includes a diverse student body of approximately 1600 students. Generally, Ferris students perform higher on state standardized tests compared to other Spokane and Washington high schools. Students in my biology classes are a mix of general education students. General classes at Ferris are representative of the whole school demographic; that include approximately 20% minority to 80% Caucasian students. The annual drop out rate is less than 5%, with almost 80% of students graduating on time. Ferris High School is located on the South Hill in Spokane, which is often thought of as a more affluent neighborhood, yet the student body ranges in socioeconomic status with approximately 30% of student receiving services for free and reduced meals. Despite 30% of students categorized as coming from low-income families, Ferris High School seems to be bridging the achievement gap with proportionally high scores across disciplines on state standardized tests in all content areas, including science.

Data were obtained through a variety of instruments in an effort to compare the effects of interventions on student content understanding, higher-order thinking, motivation, as well as teacher motivation and pedagogy. Triangulation of data was used via multiple data sources for each project focus question and cross-reference within each treatment and between treatments. Student content understanding and higher-order thinking data were gained by comparing preunit and postunit assessment, concept maps, and interviews for each unit. In addition, student motivation data were collected using student interviews, surveys, and teacher field notes and reflection. Furthermore, teacher data were gained through teacher field notes, teacher reflection, and student feedback via surveys. Table 1 shows the outline of data sources per focus question, each instrument is explained below.

Table 1
Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question: 1. What are the effects of problem-solving case studies on student on understanding of high school biology concepts?	Pre and postunit student assessments Instructor reflection journaling	Pre and postunit student interviews with concept maps	Pre and postunit student surveys
Secondary Questions: 2. What are the effects of problem-solving case studies on student higher-order thinking in high school biology?	Pre and postunit student assessments Instructor reflection journaling	Pre and postunit student interviews with concept maps	Pre and postunit student surveys
3. What are the effects of problem-solving case studies on student motivation in high school biology?	Instructor field observations and reflection journaling	Pre and postunit student interviews	Pre and postunit student surveys
4. What are the effects of problem-solving case studies on teacher motivation and pedagogy in high school biology?	Instructor post interview reflection journaling	Instructor weekly reflection journaling	Pre and postunit student surveys

Student Content Understanding and Higher-Order Thinking

For determining the effects of problem-solving case studies on student content understanding and higher-order thinking, data were collected and triangulated using student pre and postunit assessments, surveys, student interviews, and teacher reflection journaling. A sample of six students were interviewed before and after each unit throughout the capstone implementation. Two students were selected in each achievement category, low, medium, and high-achievement, based on their first semester grade; one student per category for two different sections of general biology. Interviewed students were given a concept map prompt to complete prior to the interview, and then scheduled a time during student access time Wednesday mornings, before, or after school to come in for the interview process with their completed concept map. Interviews were conducted using interview questions and were in a relaxed, ‘tell me what you think/feel/know’ setting as a conversation between me and my students. See interview questions in Appendix E and concept map prompts in Appendix F.

Students in all three sections of general biology were survey before and after each unit, and were given an opportunity to evaluate their understanding of unit topics and answer questions on their evaluation of understanding. Surveys were presented as optional to all students and students were told of the value of their honest response and no ties to their grade or teacher opinion. Student pre and postunit survey questions are in Appendix F.

All students in all three sections were given pre and postunit assessments over their understanding of concepts in each unit during the capstone implementation. Questions were open-ended and varied in the level of Bloom’s taxonomy, with questions on knowledge, comprehension, application, analysis, and evaluation. Student responses to assessment questions were ranked on a four point scale, with four as exemplary, three as proficient, two as developing, and one as emerging or vague/little understanding evident, and zero as did not answer the question. Student assessment questions are in Appendix G.

In addition to the student data above, I documented weekly reflections during my capstone implementation that included prompts on how I perceived students to understand content and use higher-order thinking in class. I also analyzed interviewed students' construction of concept maps and interview process with additional teacher reflection prompt questions. All teacher reflection prompts are located in Appendix I.

Student Motivation

Student motivation data were collected and triangulated using instructor field observations, pre and postunit interviews and surveys. Interviews and surveys were conducted as previously stated and included questions on what aspects motivated students. Interview questions are in Appendix E and survey questions are in Appendix F. In addition, teacher field observations were taken on an ongoing basis, whereby, I noted student engagement observations during learning activities during all three sections of general biology, and ranked individual student engagement at the beginning, middle, and end of selected class activities using a 10 point scale, with 10 being best. A sample of 18 students were selected to be sampled for motivation observations throughout the capstone project, including one male and one female student from high-, medium-, and low-achievement categories based on first semester grades in all three sections of general biology. An average score was then determined for each class during the same activities, and compared to motivation data gained through interviews and survey data. A general field observation chart is in Appendix J.

Teacher Motivation & Pedagogy

Teacher motivation data were collected and triangulated using weekly teacher reflective journaling and reflective journaling following student interviews. In addition, information gained through student surveys was analyzed in comparison with teacher journaling and reflection of the effectiveness of problem-solving case studies and teaching strategies on student understanding, higher-order thinking, and motivation in biology.

DATA AND ANALYSIS

Analysis of Student Content Understanding and Higher-Order Thinking Data

Quantitative data for evaluating the effect of problem-solving case studies on student content understanding and higher-order thinking in biology were obtained by analyzing student preunit and postunit assessments. Specifically, assessment questions were developed along the spectrum of Bloom's Taxonomy as follows: 1 = knowledge, 2 = comprehension, 3 = application, 4 = analysis, and 5 = evaluation. Student assessment questions were evaluated on a four point scale by ranking student understanding as follows: 4 = exemplary, 3 = proficient, 2 = developing, 1 = emerging, and 0 = did not answer the question. Results of student content understanding and higher-order thinking per preunit and postunit analysis are found in Figures 1 through 6. Student understanding of knowledge level questions is shown in Figure 1.

Student understanding at the level of knowledge showed greater gain in both treatment units compared to the nontreatment unit on DNA. Although the overall understanding of natural selection was greater than gene expression and mutation, the increase in knowledge for both units seems to be similar as shown by the slope of both treatment unit trend lines in Figure 1.

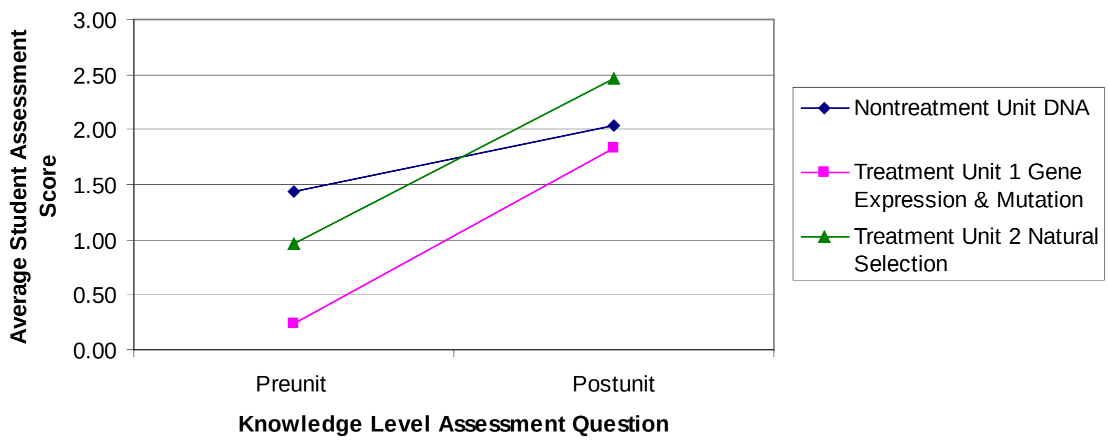

Figure 1. Average of Student Understanding of Knowledge Level Questions on Preunit and Postunit Aassessments per Unit Topic, (*N*=36).

Student comprehension question data showed mixed results between the two treatment units compared to the nontreatment unit from Figure 2 above. The comprehension question for gene expression and mutation showed a smaller gain in student understanding compared to the DNA nontreatment unit. The highest gain for understanding by far was the treatment unit on natural selection. One interesting observation regarding the difference between the two treatment units is that students struggled with content during the gene expression and mutation treatment unit and seemed to maintain misconceptions about mutations at the end of the treatment unit 1.

Furthermore, students showed increased ability to explain natural selection, including examples similar to case study content, as a result of the implementation of treatment unit 2.

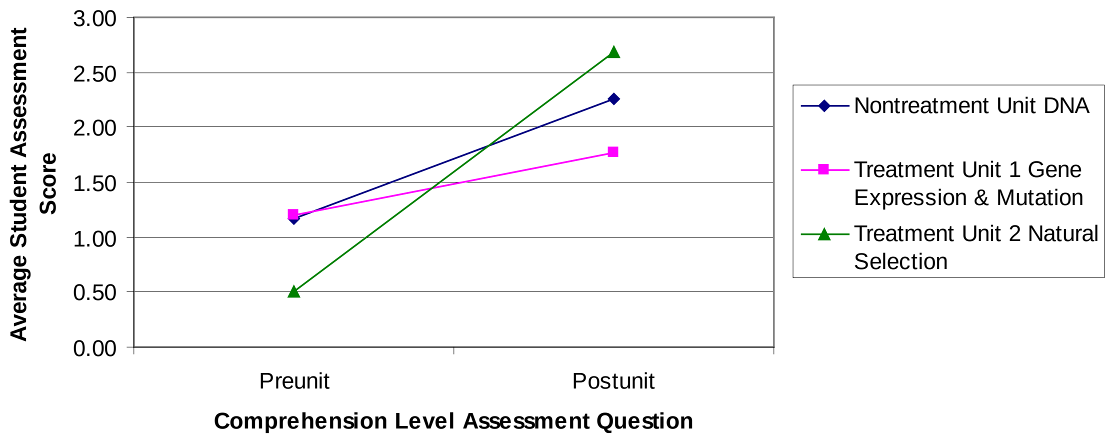

Figure 2. Average of Student Understanding of Comprehension Level Questions on Preunit and Postunit Assessments per Unit Topic, (*N*=36).

Application question data, shown in Figure 3, shows a similar trend to comprehension data in Figure 2 with relation to the lower gain in treatment unit one, gene expression and mutation, compared to the nontreatment unit on DNA. Moreover, there seems to be greater similarity in application of knowledge from preunit to postunit assessments with DNA nontreatment and natural selection treatment unit two.

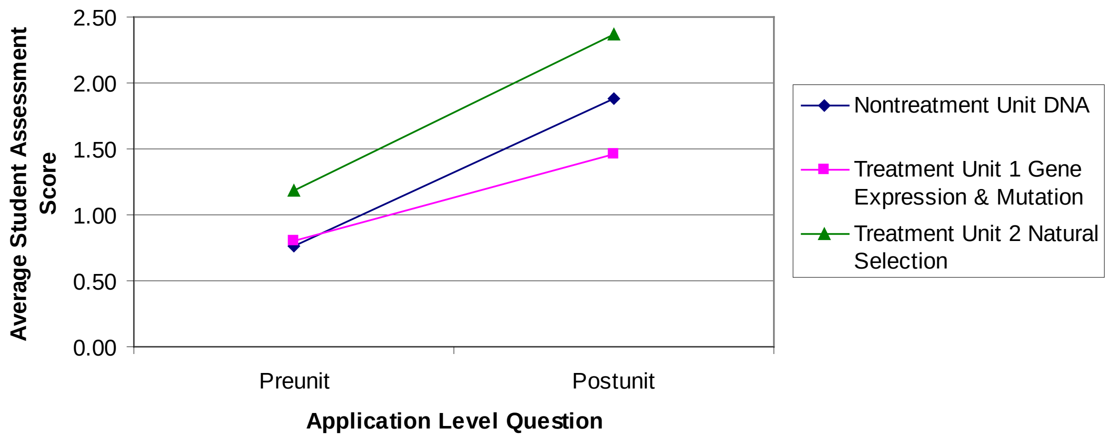

Figure 3. Average of Student Understanding of Application Level Questions on Preunit and Postunit Assessments per Unit Topic, (*N*=36).

With respect to higher-order thinking, both treatment units showed greater increase in student analysis of information compared to the DNA nontreatment unit as showed by the trend lines in Figure 4. Even more, natural selection analysis was far greater than the other two. This was also apparent in my overall teacher reflection where students seemed to not only understand natural selection better than the other two units, but also seemed to be able to use data and examples to describe their understanding of natural selection.

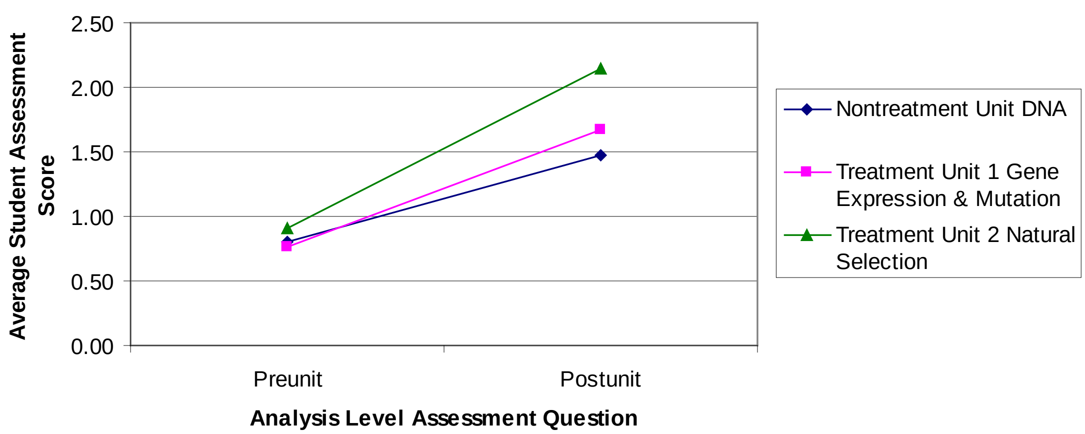

Figure 4. Average of Student Understanding of Analysis Level Questions on Preunit and Postunit Assessments per Unit Topic, (*N*=36).

Higher-order thinking with respect to the level of evaluation showed similar overall trends as student analysis with the nontreatment DNA unit showing the smallest gain, then the two treatment units in order, gene expression and mutation followed by natural selection with the greatest. One interesting aspect from student evaluation data was that the evaluation question was the only assessment question where students scored highest overall on the gene expression and mutation unit according to Figure 5. This result was likely due to students having to self-evaluate their own feelings about personal genetic testing and an increase in their ability to explain and evaluate a personal decision, which was also simulated in the case study on cystic fibrosis during treatment unit one.

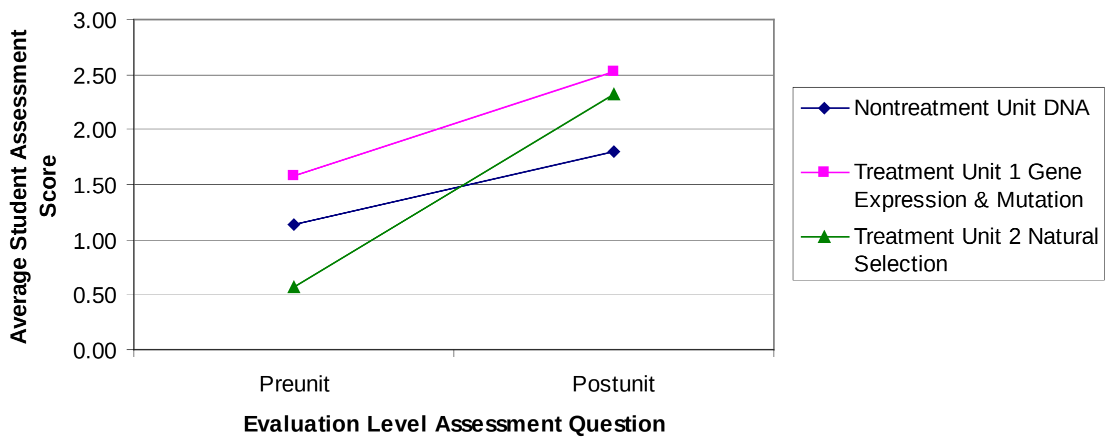

Figure 5. Average of Student Understanding of Evaluation Level Questions on Preunit and Postunit Assessments per Unit Topic, (*N*=36).

Overall, data showed a positive improvement of student content understanding with knowledge level questions for both treatment units compared to nontreatment unit as shown in Figure 6. Though treatment unit one on gene expression and mutation showed inconclusive evidence of improved content understanding, treatment unit two on natural selection showed greater student improvement of understanding and higher-order thinking across all question types spanning Bloom's Taxonomy. These data were consistent with teacher weekly and interview reflection data noting that students struggled with content and process information in both the DNA nontreatment unit and gene expression and mutation treatment unit one, yet a large proportion of students seemed to have good content and process understanding with natural selection treatment unit to the point of explaining thoroughly and using evidence and examples to support their understanding.

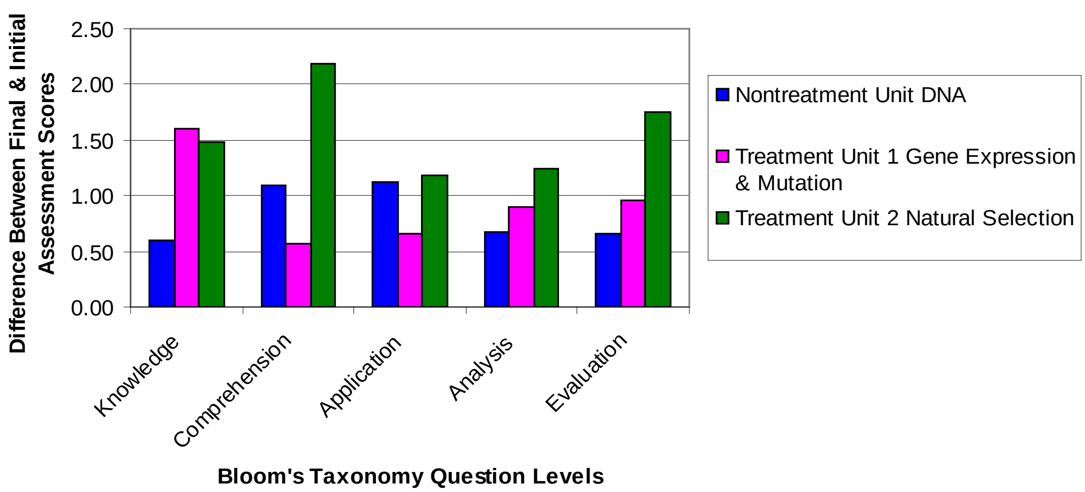

Figure 6. Difference Between Preunit and Postunit Assessments Scores, (*N*=36).

In addition to the student assessment data, student understanding and higher-order thinking data were collected and analyzed via student surveys. Students were asked to rank themselves using a Likert-scale for how they feel/felt they understood and were able to apply their understanding of topics to real-world scenarios. Results of student content understanding and higher-order thinking from student surveys are found in Figures 7 and 8.

According to Likert survey data in Figure 7, student felt they understood more at the end of the unit as compared to the beginning of each unit. Many students still did not feel confident in their understanding of gene expression and mutation at the time of the postunit survey, which was consistent with teacher observations and student interview data. Most students were somewhat confident in their understanding of DNA and natural selection with treatment unit two on natural selection again showing the greatest increase in student perception of understanding. One interesting aspect of teacher observation and student interviews was that students seemed to come with little prior knowledge of natural selection, but perceived and showed the greatest gains and knowledge with this treatment unit.

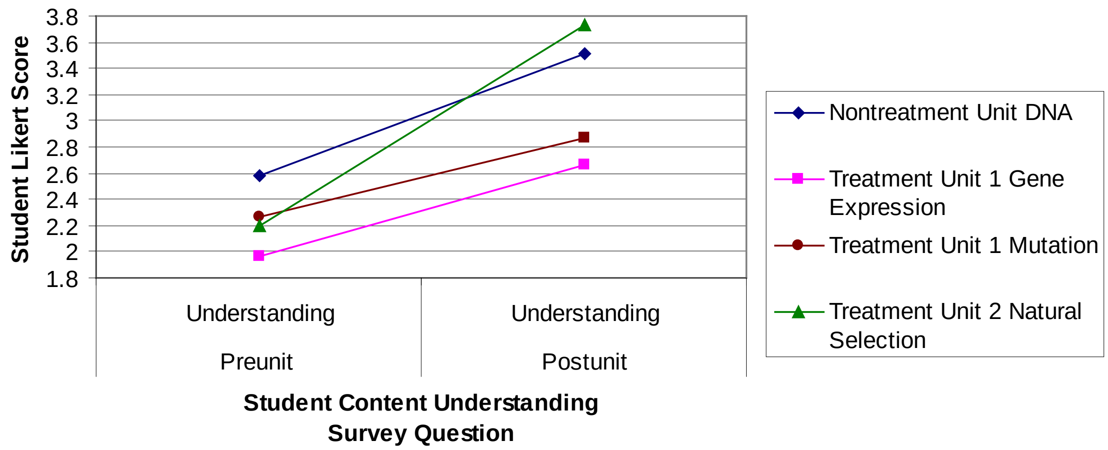

Figure 7. Average Student Perception of Content Understanding per Unit Topics, (*N*=36). Likert scale 1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree, 5 = strongly agree

Student survey questions for higher-order thinking asked students to rank themselves on their ability to apply their understanding of each major unit topic to real-world scenarios. Figure 8 shows that average student ranking began around the same level for both treatment units, but gene expression and mutation treatment unit one showed small gains compared to the huge gains students felt they acquired through natural selection treatment unit two. Though the difference between treatment units is unknown, in reading many student survey responses to what helped students or needed improvement was that the difficult molecular level case studies were interesting but challenging with some stating they did not really understand; where as, students understood and could relate to the many natural selection case studies that were easier to understand and relate back to themselves in addition to simulation activities that put case studies in action in the classroom.

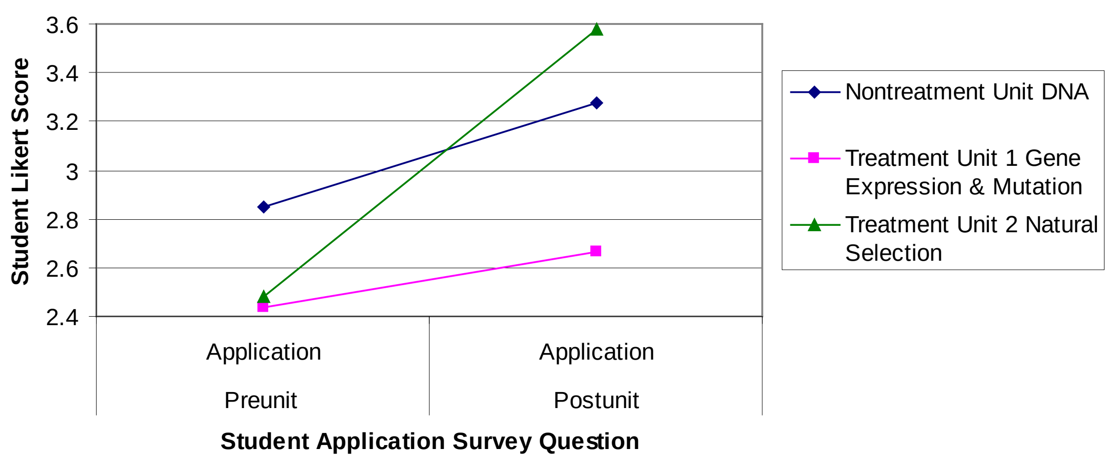

Figure 8. Average Student Perception of Higher-Order Thinking per Unit Topics, (*N*=36). Likert scale 1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree, 5 = strongly agree

Analysis of Student Motivation Data

Quantitative data for evaluating the effect of problem-solving case studies on student motivation in biology were obtained by analyzing student preunit and postunit surveys. Students self-assessed their motivation of learning different unit topics in biology using a Likert scale. Results of student motivation from preunit and postunit surveys are found in Figure 9.

Students showed an increase in motivation for the nontreatment DNA topics and a large increase in motivation over the course of the natural selection treatment unit 2, which was consistent with teacher observations and student interview data that showed students enjoyed and were interested in learning about natural selection. However, Figure 9 also shows a decrease in motivation for both mutation and gene expression, with gene expression having the greatest decline. This negative trend may be due to a variety of factors that include students not feeling they understood the topics as observed via interview, survey, and field notes.

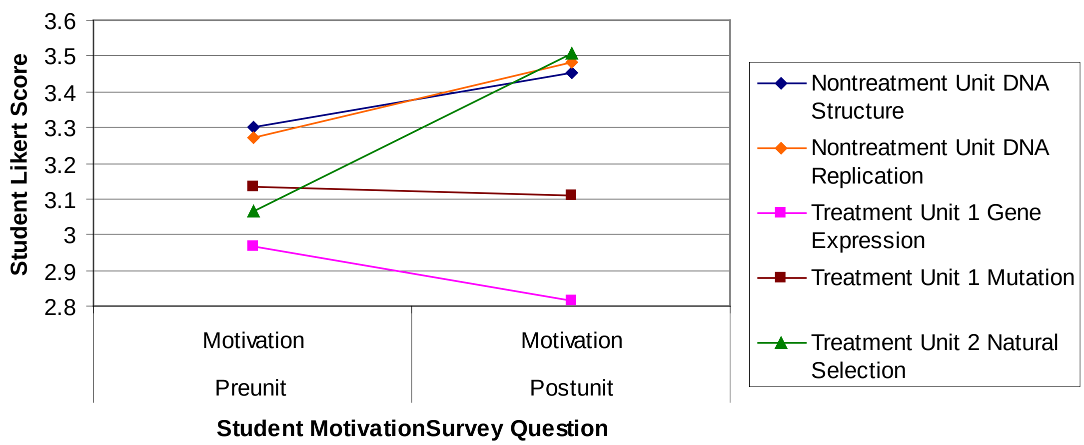

Figure 9. Average Student Motivation per Topics per Student Likert-Surveys, (*N*=36). Likert scale 1 = strongly disagree, 2 = disagree, 3 = neither agree or disagree, 4 = agree, 5 = strongly agree

In addition to survey data, student motivation was collected during teacher field notes based on student engagement in learning. Student engagement data was averaged for each unit, shown in Figure 10.

Students showed greater engagement in learning activities in both treatment units compared to the nontreatment unit on DNA. Even more than the quantitative data in Figure 10, once case study implementation began there was a noticeable increase in student engagement with many students expressing excitement in crime scene scenarios and hands-on problem-solving scenarios. In addition, I noticed an increase in participation in whole class discussions by students who rarely or never shared ideas in class. In addition, many students shared how they were motivated by case studies in interviews and surveys including how they appreciated the connection to real-life, even though some expressed challenge in fully understanding the science concepts themselves.

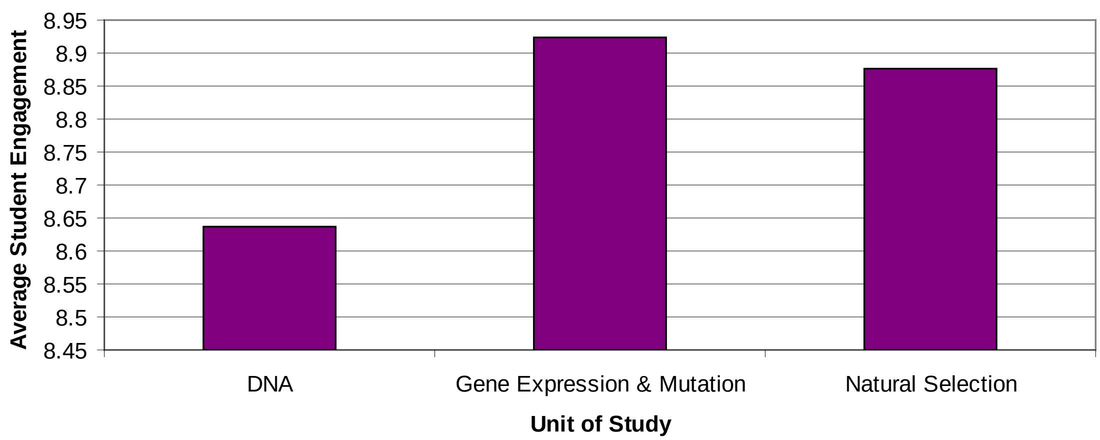

Figure 10. Average Student Engagement per Teacher Observation Field Notes, (*N*=36). Activities were rated on a 10 point scale, where 10 was completely engaged and 5 was not engaged at all.

Analysis of Teacher Pedagogy and Motivation Data

Teacher pedagogy and motivation qualitative data was collected via teacher observations and reflections in conjunction with student feedback via surveys, assessments, interviews, and field notes. I found that when students were motivated and expressed excitement in learning activities, or wanted to learn more about a topic, that my motivation increased as well. Specifically, students showed increased motivation and engagement during video-based case studies and asked more in depth questions and were interested in watching and learning more.

Teacher reflection showed mixed feelings on the stand-alone print case studies. Unlike the positive student comments and observations of engagement in video case studies, students working in groups did not appear as excited about print only problem-solving case studies. Later, when reviewing student surveys, I noticed that many students made positive comments towards the print case studies on cystic fibrosis, stating they knew people with cystic fibrosis or could relate to genetic disorders affecting families. Similar comments were noticed with the MRSA case study also including students explaining they did not know about antibiotic resistance or that this was a good example of natural selection in the real world. All in all, though my initial reflection was more somber in motivation to use stand alone case studies, I found positive student feelings towards learning and understanding improved motivation and the likelihood I would use similar stand-alone case studies in the future.

In looking at student assessment, survey, and interview data, I was very intrigued by the large difference of motivation and understanding between the two treatment units. Although I was very motivated by students continually making comments during interviews and surveys about liking real-world scenarios and hands-on activities, I felt there was a difference between the treatment units in these two aspects that may have led to the natural selection unit being more effective in student understanding, higher-order thinking, and motivation. One pedagogical shift I reflected on in continuing to use problem-solving case studies my classroom came from the many student comments that expressed their difficulty understanding some of the print and video case studies and a continual desire to have hands-on activities to help students learn. Overall, I feel that the natural selection unit had all three components, print, video, and hands-on case study application and that all three together seemed to have the greatest impact on student understanding and motivation.

INTERPRETATION AND CONCLUSION

The implementation of problem-solving case studies showed overall improvement in student understanding of high school biology content. There was a large difference in student understanding of both treatment units at the Bloom's Taxonomy level of knowledge compared with the nontreatment unit. I found this to be quite interesting since most students had greater prior understanding of the nontreatment topics on DNA in their preassessments. Since both treatment units showed a great deal of student growth in understanding at the knowledge level, I believe that the implementation of problem-solving case studies must have some positive effect on student understanding, though it is hard to know what the actual mechanism of improvement may have been.

Student improvements of understanding at the comprehension and application levels were mixed between treatment units from both assessment and survey data. While there were great gains in both levels of understanding with the second treatment unit on natural selection, treatment unit one on gene expression and mutation was very low even when compared with the nontreatment unit. Furthermore, student understanding was lower for treatment unit one when comparing the difference between preunit and postunit assessments, as well as, students survey data from the Likert-scale and qualitative data in many students expressing difficulty in understanding both gene expression and mutation. With mutation I noticed that student preconceptions and misconceptions seemed to show up in the postunit assessment and may have been cause for lower performance of understanding. This aspect was addressed with students as we continued to talk about the role of mutations in providing variation needed for natural selection to occur in treatment unit two. Moreover, I believe that in six years of teaching biology at a variety of levels that students have the greatest difficulty in understanding molecular biology, including gene expression and protein synthesis. I had originally planned on having students do a simulation activity of protein synthesis; however, I did not do this due to a conflict with the same activity in a successive course per other collaborative teachers in my department. Finding that when mixing of problem-solving case studies with hands-on simulation activities students gained the most benefit of understanding was evident with the natural selection unit, I would include such an activity in future years in hopes that this combination would improve student content understanding the most.

The effect of problem-solving case studies on student higher-order thinking in biology was improved with both treatment units compared with the DNA nontreatment units. Again, the natural selection treatment unit showed the greatest amount of improvement in higher-order thinking skills. While it is likely that the hands-on simulation case studies were helpful in students being able to analyze and evaluate on their assessments, in addition to video and print case study scenarios, I feel that the continual exposure to real-world data and problems has a compounding effect. This was noted in my teacher reflection journal where I stated that the more experience students gained with data analysis and evaluation, the better they were able to answer such questions over time.

Though the student assessment and teacher reflection data showed great improvement of higher-order thinking with problem-solving case study units, students were mixed in their perception of content application to real-world scenarios. Student surveys showed some improvement perceived by students with higher-order thinking related to gene expression and mutation, yet smaller than other units. I noticed many comments of how the case-studies were interesting but that they were difficult to relate to content. Again this seems to be a challenge with connecting molecular processes to tangible real-world applications. Natural selection, on the other hand, showed student perception of relating to real-life had a substantial amount of improvement. This was also consistent with the number of students who could answer questions and give specific examples on assessments and during interviews.

Student motivation during the implementation of this capstone project was varied according to the data. Teacher field observations showed some improvement of student engagement during both problem-solving case study units compared to the non-treatment; however, student motivation data from student surveys showed a decline in motivation for learning about gene expression and mutation. It is likely that this decline was directly related to student perception of understanding content, as was evident in multiple student comments on survey questions. In contrast, students ranked and expressed the greatest motivation with the natural selection treatment unit and subsequently the highest content understanding improvement in almost every level of Bloom's Taxonomy on the assessment over natural selection. Even more, student comments on what motivates them to learn in biology were consistently about hands-on activities and real-world application. Student motivation during natural selection was likely highest since both hands-on activities and real-world applications were included and combined resulting in an overall benefit to student motivation and understanding in biology.

As a teacher, I found the implementation of problem-solving case studies was very motivating and plan to shift my future pedagogy to include more problem-solving scenarios with hands-on aspects as well. Personally, I love to share about all of the amazing applications of the science concepts in my classroom, but often find that due to time or a lack of student engagement I pass over many of these opportunities. In deliberately including real-world applications in biology content, my teacher motivation improved because I was able to share the reason I am so passionate about biology. Through the process of this project, I became more aware of student desire to have a combination of hands-on and real-world learning opportunities, and then saw the amazing gains to content-understanding, higher-order thinking, and student motivation.

In the future I would be interested in looking at the effect of hands-on simulations of real-world problems and scenarios to discover how this, in conjunction with video and print case-studies, impacts student understanding and motivation in the science classroom. A personal observation I found throughout this capstone process was my own increased interest with student motivation. I found that though my focus question was about student understanding of biology content, I became increasingly interested in how and why students were motivated. Future action research in my classroom will likely include looking at what positively impacts student motivation, and subsequently, how motivation impacts student understanding and higher-order thinking in the science classroom.

VALUE

Throughout the implementation of problem-solving case studies for the purpose of teaching high school biology content, I gained a new perspective and outlook of what helps and motivates students in their learning and what my larger goals are for my students. Though I train my students to be successful in future science courses at the high school and college level, it is likely that many of my students will not go on to a future career in the field of science. Knowing that I feel my responsibility is to give students an opportunity to gain understanding of important science concepts, but I have found that content focus alone is not enough for a majority of my students. Time after time as I reviewed student comments on surveys and in interviews I learned of the deep desire to find value in what they are learning and a need to be able to relate biology content back to their own lives and the world around them. While this may be intrinsic for many of our up and coming young scientists, it is not the case for the whole of students we teach, i.e. everyone benefits from real-world applications in helping them learn.

From my literature research on problem-solving case studies as teaching strategies in the high school setting, I found that though there have been some inquiry and problem based learning models but the larger use of these strategies are found in postsecondary education. There may be a lot to learn for those of us at the high school level about how problem-solving scenarios can enhance our students' understanding and motivation in a variety of content areas. Furthermore, the data and observations from this study found there may be many benefits to a variety of real-world scenarios, but including hands-on simulations seemed to heighten the overall effect of problem-solving case studies on student understanding in biology. I believe there is room for more research and development for shifting towards such a learning model in high school level science education, and would personally pursue both the combination of hands-on simulations of case studies and an in-depth look at what motivates student learners and how motivation impacts content and process understanding in science.

As I come to the end of this capstone project, and the beginning of a new way of teaching biology, I found one very important reflection; the classes and content I am excited about always had to do with the story of discovery and real-world application. In addition, these scenarios and real-life situations became real to me as I conducted scientific studies that related back to what I had learned in case studies. As my depth of knowledge grew, I was able to analyze and suggest solutions for complex problems in biological systems, and fell in love with all things science. My students are no different from me as learners, they want to understand, value, and be able to apply their knowledge to their own lives. My hope is to continue to develop problem-solving case studies and other strategies that will help motivate my students to pursue knowledge of diverse subjects and become life-long learners.

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APPENDICES

APPENDIX A

PROJECT TIMELINE

Project Timeline

The following is the timeline for the implementation of this capstone project to begin in January of 2011.

January 25 – DNA nontreatment preunit assessment and survey. Teacher journal/reflection/field notes ongoing. Preunit interview with concept map scheduled outside of class time.
January 26/27 (Block Period) – DNA the genetic molecule, role of DNA, & building DNA inquiry/model activity
January 28 – DNA structure
January 31 – DNA replication
February 1 – **DNA postunit assessment, survey, and interview with concept map**
February 2/3 (Block Period) – **Gene expression & mutation preunit assessment, survey, and interview with concept map**; DNA extraction
February 4 – Umbrella Assassination case study part I & II
February 7 – Proteins & enzymes, complete Umbrella Assassination case study part II
February 8 – Enzymes, Tokyo Sarin Subway Attack Scenario, Start Enzyme Investigation
February 9/10 (Block Period) – Enzyme investigation (temperature & enzymatic rate), complete Umbrella Assassination video
February 11 – Protein problems & genetic diseases mini research project/poster
February 14 – Central dogma & RNA, Biological Effects of Ricin
February 15 – Protein synthesis
February 16/17 (Block Period) – Protein synthesis, cystic fibrosis stand alone case study
February 22 – Complete cystic fibrosis case study, snow white bambi case scenario I, mutation
February 23/25 (Block Period)– Mutation, snow white bambi scenario part II (Snow Day 2/24)
February 28 **– Gene expression & mutation postunit assessment, survey, and interview with concept map**
March 1 **– Natural selection preunit assessment, survey, and interview with concept map**

March 2/3 (Block Period) **–** Mutation & variation, snow white bambi part III (modified wooly worm activity), variation lab
March 4 **–** Variation & natural selection online activity
March 7 – Camouflage adaptations, natural selection reading
March 8 – No class
March 9/10 (Block Period) **–** Natural selection reading, lecture/discussion, video examples
March 11 – Mystery of Black Death case study
March 14 **–** Mystery of Black Death case study
March 15 – Mystery of Black Death case study, MRSA case study
March 16/17 (Block Period) **–** MRSA case study (state testing days)
March 18 **– Natural selection postunit assessment & survey**
March 21 – **Natural selection postunit interview with concept map**

APPENDIX B

DNA NONTREATMENT UNIT LESSONS AND MATERIALS

1/25/2011 Introduction to DNA

Students took the preassessment, preunit survey, and preunit concept map for DNA. Students brainstormed prior knowledge about DNA by sharing with partners then as a whole class. Students watched an Untamed Science video, which is part of our Miller & Levine Biology (2010) curriculum package.

1/26 or 1/27/2011 DNA, The Genetic Molecule & DNA Model Inquiry

Students were asked how we know DNA is the molecule of heredity, or genetic molecule, i.e. what is the scientific evidence. Students then read p. 338-341 about the identification of DNA as the genetic molecule (Miller & Levine, 2010). While they read the text excerpt, students were asked to diagram and summarize the three major experiments that confirm DNA as the molecule of heredity: Griffith, Avery, and Hershy-Chase experiments. Students were then asked to continue to read about the role of DNA and complete a graphic organizer in their science notebooks. Following the reading activity, students shared what they learned and questions they had about text information. A whole class discussion of our evidence for DNA being the genetic molecule and the role of DNA followed with the inclusion of student questions.

After the discussion about DNA is the genetic molecule, students began a paper DNA structure activity. Each student was given a paper with three different components of a nucleotide, phosphate, deoxyribose, and a nitrogen base, and then asked to try to assemble one nucleotide out of their pieces. After students determined one nucleotide, they were grouped with other students to try to assemble a short section of DNA. Students recorded their observations with complementary base-pairing, antiparallel strands, and types of bonds. Groups continued to combine until we had one large strand of DNA for the entire class. Students drew a section of their DNA molecule in their notebooks. Following the construction process, we had a whole class discussion on the structure of DNA and the bonds, including using paperclips for the hydrogen bonds between the two strands of DNA.

1/28/2011 DNA Structure

Students began by writing what they already know and what they were interested to learn about DNA. Students were given a set of data that showed base paring percentages and asked to analyze what the data meant in their notebooks, then discussed as a whole class. Students read about DNA structure in their text book and completed a reading worksheet. Following the reading, students received notes via direct instruction about the structure of DNA. Finally, students watched a video on public genomes at
http://www.pbs.org/wgbh/nova/body/public-genomes.html
and discussed the pros and cons of making our genetic make-up public information.

1/31/2011 DNA Replication

Students read and answered questions about the purpose and process of DNA replication in living organisms. Students then took notes during a short section of direct instruction about the process of DNA replication. Towards the end of class, students watched the segment of “The Secret Life of DNA” (Thirteen/WNET, 2003) about DNA structure and replication.

2/1/2011 DNA Assessment

Students completed their DNA postunit assessment and survey, and then completed an online DNA quiz.

2/2 or 2/3/2011 DNA Extraction Lab

Students were given whole group instruction on the process and purpose of extracting DNA from organisms. Students conduct a DNA extraction lab using strawberries with the protocol in Biology Lab Manual (Miller & Levine, 2010). Students keep record of their observations in their student notebook.

APPENDIX C

TREATMENT UNIT 1 GENE EXPRESSION AND MUTATION LESSONS AND MATERIALS

2/2 or 2/3/2011 Gene Expression & Mutation Preunit

Students completed their preunit assessment and survey for gene expression and mutation treatment unit 1.

2/4/2011 Umbrella Assassination Case Part I & II

On the first day of treatment unit 1 over protein synthesis and regulation, students watched a video segment and were given introductory information in a handout printed from Secrets of the Dead (Thirteen/WNET, 2006) for the real life case of Georgi Markov, a Bulgarian defective who was assassinated in 1978 near the Waterloo Bridge in London. Students were given the part I, Background, on the account of Georgi Markov's assassination, asked to discuss the following questions in groups of three to four students, and then present a summary of their group's answers; what do you think the caused of Georgi Markov's death, why do you think the man said, "I'm sorry," when he ran into Georgi Markov, if you were Georgi Markov what would you have done when you noticed blood on your jeans, as a modern day Sherlock Holmes, what would your next step be in solving Georgi Markov's mysterious death? At the end of class students watched an additional video segment on the clues and evidence of the case study.

2/7/2011 Proteins & Umbrella Assassination Case Part II

Students started class with a T-chart reading activity on the structure and function of proteins using their text book, p. 48-49 (Miller & Levine, 2010). Following the reading, students discussed and took notes on to review the structure and function of proteins; a review from the beginning of the school year. Students were then given the second hand out from Secrets of the Dead (Thirteen/WNET, 2006) for part II, Clues and Evidence, that gave insight into the investigation following Markov's death. Specifically, the article talks about tracking the poison to ricin and explained the physiological effects of ricin, including the interference in making proteins, and the evidence linking ricin to the death of Markov. Groups discussed and presented their ideas to the following questions; what evidence did the scientists and investigators use to determine ricin as the cause of Markov's death, how is ricin different from other toxins, what are the physiological effects of ricin on humans, why would the inability to make proteins lead to human death, i.e. what is the purpose/function of proteins in living things? After the case study activity, students read and started a reading worksheet over p. 50-53 in their text book, Miller & Levine Biology (2010), about enzymes.

2/8/2011 Enzymes & Rates of Reactions

Students completed their enzyme reading and worksheet. Following the reading, there is a lecture/discussion about the function of enzyme proteins and factors that affect proteins. Students were then given a short scenario of the Tokyo subway attack in 1995 using Sarin gas that includes information about the way enzymes may be inhibited.

Students are asked to discuss and analyze the information from the Tokyo incidence and compare the information with what they know from Markov's assassination, explain if they think there is any similarity to Markov's case, and explain what additional information they need to crack Markov's case. Following the comparison of sarin and ricin toxin affects, students were introduced to factors that effect rates of reactions using enzymes including temperature.

2/9 or 2/10/2011 Effect of Temperature on Enzymes Lab

Students look back in their notes and explain the factors that affect enzyme function. As a whole class, we brainstorm ways to test enzyme action with different factors in the classroom. Students are presented with materials they may use to create their own enzyme investigation; yeast catalase, filter paper squares, 1-3% hydrogen peroxide, and possibly different pH solutions. Students were given a demonstration for how they could test enzyme action and calculate the rate of reaction using the given materials. Following the demonstration, groups of 3-4 students worked together to design an experiment testing factors affecting enzyme function, completed a proposal of their experiment, and then, once approved, recorded their investigative question, hypothesis, procedure, and data table in their science notebooks. Experiment is similar to Miller & Levine Biology (2010) p. 54 with a substitution using yeast as the catalase and more open exploration with temperature, concentration of enzymes or substrate, and pH. Students then conducted their experiment on factors affecting enzymatic action. Following their data collection, students analyze their data then write independent lab reports to be turned in for peer-assessment and teacher evaluation. Students watched the end of the Umbrella Assassination video while they worked on their lab reports.

2/11/2011 Protein Problems Poster

Students researched and created and informational poster on a particular problem with a protein's function due to a genetic disorder. Students were required to include the name of the protein, its function, chromosome location, how the protein problem caused the disease, and how the trait was inherited, and then given options of other information they could include. Upon completion students shared their poster with their classmates and peer reviewed each other's work

2/14/2011 Central dogma & RNA, Biological Effects of Ricin

Students asked to look back in their notes from earlier in the year and/or recall the location of protein synthesis in their notes. Then students were introduced to the central dogma of molecular biology with a flowchart that showed the progression from DNA to RNA to protein to trait, and were asked which of the terms on the board they were not familiar with; which they responded RNA. Students were given a graphic organizer on RNA, which they completed while reading pages 362-365 in their text book. Following the reading activity, we had a whole class discussion of the role of ricin in disrupting ribosomal RNA and therefore disrupting the making of proteins. Class concluded with a clicker quiz on RNA.

2/15/2011 Protein Synthesis

Students read a small text excerpt and reviewed the central dogma and RNA from the previous day. Students took notes on the big ideas with protein synthesis; that we need to make proteins to survive and do so by making a copy of a gene on our DNA into RNA and then send that to a ribosome where we put together the amino acid building blocks to make a protein. As a whole class we took a tour of the protein synthesis process at http://www.lew-port.com/10712041113402793/lib/10712041113402793/Animations/Protein Synthesis long.swf, and as a class we documented 10 steps of protein synthesis. The remainder of class was spent practicing transcription of a pseudosegment of a gene of DNA into messenger RNA in table partner groups.

<u>2/16 or 2/17/2011 Protein Synthesis & Cystic Fibrosis Stand Alone Case Study</u>

Students reviewed the overall picture of protein synthesis and went over the transcription activity from the day before again. Next students were introduced to codon charts and then took the messenger RNA code, and with their table partner, worked to translate the messenger RNA into a sequence of amino acids. Students were then placed into groups and were given instructions for using case study handouts as an introduction to a gene mutation that causes cystic fibrosis in humans. The “Sometimes its All in the Genes” case study was developed by Anne Galbraith and David Howard of the Department of Biology at the University of Wisconsin (National Center for Case Study Teaching in Science, 2003). Students worked in groups of three to four on the first two sections, out of four parts, sharing their ideas, opinions, and conclusions with the whole class at the end of each section.

2/22/2011 Cystic Fibrosis Stand Alone Case Study & Snow White Bambi Scenario Part I

Students completed part three and four of the cystic fibrosis case study from the previous day. Following, students were introduced to a scenario involving a local/regional teenage girl out on her first hunting trip with her dad and brothers. With adrenaline rushing the girl shot her first deer, but upon getting up and close to the deer she sees the agony of the dying deer in conjunction with a rare site, an albino deer. Students were asked to brainstorm how it is possible for an organism to be an albino mutant, give examples of other albino organisms, and pose how they thought mutations occurred. Students read a section on mutations in their text book, p. 372-375, and answered questions over the section in their science notebooks (Miller & Levine, 2010).

2/23 or 2/25 Snow White Bambi Part II & Mutations

Students completed the reading questions over mutation from the day before at the beginning of class. Following the reading questions students discussed and took some notes over mutation. They were then asked whether the albinism gene in the deer was helpful or harmful and were Students discussed ideas of homework on how albino genes affected organisms, and the benefits/harms of albino and other mutations. Next, the class transitioned into a controversy over the protection of albino deer in their community. Students were given the controversy scenario of a new law that protects the albino deer from being hunted in the region. Student teams were assigned to different interest groups that had a variety of stances on the new law, were given time to discuss and come up with their viewpoint on the no hunt policy, and then engaged in a town meeting setting over the controversy.

2/28/2011 Gene Expression & Mutation Postunit

Students completed their postunit assessment and survey for gene expression and mutation treatment unit 1.

APPENDIX D

TREATMENT UNIT 2 UNIT NATURAL SELECTION LESSONS AND MATERIALS

<u>3/1/2011 Natural Selection Preunit</u>

Students completed their preunit assessment and survey for natural selection treatment unit 2.

<u>3/2/2011 Snow White Bambi Part III</u>

Students reviewed mutation and were introduced to the concept of variation in populations via mutation and sexual reproduction. Students were then introduced to the hypothesis of a near future Northern Hemisphere mini ice-age being caused by the turning off of the mid-Atlantic current, and how this ice-age could be triggered by current rises in global ocean temperature (European Science Foundation, 2009). Student groups discussed how a mini ice-age would regionally impact people and organisms in the Pacific Northwest. Groups shared their ideas about ice-age impacts and engaged in general classroom discussion and brainstorming.

Next students were asked to revisit the albino deer scenario in the cooler, snow-covered climate. Students were asked to predict how the new environmental conditions would impact both regular dear and albino deer. Students engaged in a think, pair, share session, and then the whole class brainstormed ways we could test the effects of climate change using models; something often done in real science to project future outcomes. Finally, students took part in a predation simulation by distinguishing which deer would more likely be preyed upon in different climate/environmental conditions. We used a simulation, modified from the original Wooly Worm and Natural Selection (House, 1986), of finding prey of different phenotypes on different color backgrounds. Students collected and analyzed data and then wrote a short creative story about the future freeze and its impact on deer populations.

3/4/2011 Variation & Natural Selection Online Assignment

Students visited the http://evolution.berkeley.edu/evolibrary/article/evo_25 website and explored information about variation and natural selection and documented information and examples in their notebooks.

3/7/2011 Natural Selection

Students discussed the natural selection and adaptations by reviewing the results of the albino deer data results and discussing camouflage, and then watching a short video clip on camouflage at http://www.pbs.org/wgbh/evolution/library/01/1/l_011_03.html . Students were then assigned reading guided by a worksheet in their text over artificial selection, natural selection, and common descent.

3/9 or 3/10/2011 Natural Selection

Students complete the last section of the reading worksheet from the previous day over the natural selection example of the Galapagos finches studied by Rosemary and Peter Grant in their text book. As a whole class, we reviewed each section and discussed the ideas of the reading and worksheet guide. Next, students took notes and discussed Darwin's big ideas and the concept of evolution by natural selection. The remaining time was used to view video examples of natural selection from the PBS evolution website, including each of the following:

- Adaptive Compromise – Sickle Cell
  http://www.pbs.org/wgbh/evolution/library/01/2/l_012_02.html
- Coevolution – keeping up with the Jones'
  http://www.pbs.org/wgbh/evolution/library/01/3/l_013_07.html
- Why Sex? … *increases variation;* Red Queen Hypothesis = Coevolution
  http://www.pbs.org/wgbh/evolution/library/01/5/l_015_03.html
- Why Sex? … *sexual selection*
  http://www.pbs.org/wgbh/evolution/library/01/6/l_016_09.html

3/11/2011 Mystery of Black Death Case Part I & II

Students watched the first part of Secrets of the Dead Mystery of Black Death video at http://www.youtube.com/watch?v=nfCbJExNKEE&NR=1 and took notes over the information and evidence presented in the video. Next students were asked to discuss and explain the biological reason for death by plague and how some individuals were able to survive. Students worked in small groups to read, gather more information, and answer questions using the Background handout from the Secrets of the Dead website (Nova Online/WGBH, 2000). Next, students watched part two of the video and collected more information.

<u>3/14/2011 Mystery of Black Death Case Part III</u>

Students reviewed what they already knew about the black plague with their table partners and discussed briefly as a whole class. We then viewed part three of the video that went into detail about the CCR5 delta 32 gene mutation and the survival of the plague. Following the video, students read and discussed the Clues and Evidence handout information from the Secrets of the Dead website in small groups, and then as a whole class (Nova Online/WGBH, 2000).

<u>3/15/2011 Mystery of Black Death Case Part IV</u>

Students completed the case study by watching part four of the videos that linked the CCR5 delta 32 gene mutation to resistance of HIV and read the Interview handout and discussed with their group (Nova Online/WGBH, 2000). We completed the class with a general discussion about chance mutations causing increased survival, i.e. a human example of natural selection.

<u>3/16 or 3/17/2011 MRSA Stand Alone Case Study</u>

Students worked together in small groups to complete the MRSA antibiotic resistance stand alone case study developed by Lemons and Huber (2007). Groups worked together to discuss questions and analyze data. Furthermore, students were introduced to biotechnology techniques and data in the process of this case study. At the conclusion of the case we conducted a discussion and summary on the use, problems, and regulation of antibiotics.

3/18/2011 Natural Selection Postunit

Students completed their postunit assessment and survey for natural selection treatment unit 2.

APPENDIX E

STUDENT INTERVIEW

Student Interview Questions

Student interviews were conducted with student generated preunit and postunit concept maps. The interviews centered on content understanding, higher-order thinking, and student motivation. The following are general questions that guided the interviews with students that were conducted in a discussion format where students shared their understanding and motivation verbally, and I documented student responses by taking notes over their comments, explanations, and opinions.

1. Explain how you created your concept map and why you placed and connected concept they way you did.
2. Look at the sample concept map.
    a. Show me an example you would add to this concept map.
    b. Why you would add this example?
    c. How does this example relate real life?
3. Now, explain how you connected your understanding of concepts to real-world scenarios or problems on your concept map.

4. What activities help you to understand biology?
5. Do you look forward to doing biology activities? Explain why or why not.
6. Preunit: What do you think will motivate you to learn about the next unit topic? Why or how will this motivate you to learn?
7. Postunit: What motivated you to learn in our topic of study? Explain.
8. Are there any other questions that I should ask? Please ask and answer your additional question(s).

APPENDIX F

STUDENT CONCEPT MAP

Concept Map Assessments

Students, who were also interviewed, were given general terms for each unit and asked to complete a pre and postunit concept map and bring their complete concept map with them to their interview, which were times set outside of class time and included Wednesday morning student access time, before, and after school. Students were assured that their concept map ideas were valuable and would not be counted towards their grade, but rather help in the process of understanding their thinking and understanding. Concept maps were kept, analyze using the concept map rubric, and analyzed for individuals and between student achievement categories. Student concept map instructions and word banks were as follows:

Please create a concept map using the words provided with the unit topic as your central idea. Bring your concept map with you to your interview so we may discuss your understanding and ideas. You concept map is not for a grade, but your participation and sharing your understanding is very important to me. Please remember to use connecting words in your concept map so I can fully understand how you are connecting ideas. You may use additional words and examples if you would like, but need to use all of the words provided in the box below.

Concept map words for DNA nontreatment unit **Begin with the word DNA.**			
DNA	DNA Structure	DNA Function	DNA Replication
Bonds	Base Pairing	Discovery of DNA	

Concept map words for Gene Expression and Mutation treatment unit 1 **Begin with the word Gene Expression & Mutation.**					
DNA	RNA	Ribosome	Transcription	Translation	Mutation
Concept map words for Natural Selection treatment unit 2 **Begin with the word Natural Selection.**					
Artificial Selection	Natural Selection	Adaptation	Survival of the Fittest		
Variation	Mutation				

Scoring Rubric for Concept Map

Map Component	Possible points	Awarded points	Special things noticed about map
Proposition			
Clear and meaningful to the central topic	2 each		
Beyond given set of terms	3 each		
Not properly linked	1 each		
Vague	1 each		
Branch			

Top	1		
Successive branches	3 each		
Levels of hierarchy (general to specific)	5 each level		
Cross Links	10 each		
Examples	1 each		
Total			
Overall reaction to map and special things noticed.			

Adapted from Novak and Gowin (1984).

APPENDIX G

STUDENT SURVEYS

Nontreatment Pre and Postunit Survey Questions: DNA

This survey is for the purpose of gaining student feedback in biology. This survey is completely voluntary. If you are not comfortable answering any question you are welcome to stop at any time. Your participation/nonparticipation in this survey will not affect your grade or class standing.

Rank yourself on a scale of 1-5, with 5 being best, for each of the following:

5	4	3	2	1
Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree

1. _____ I feel/felt confident in my understanding of DNA.
2. _____ I feel/felt motivated to learn about DNA structure.
3. _____ I feel/felt motivated to learn about DNA replication.
4. _____ I feel/felt I can apply my understanding of DNA to real-world scenarios and problems.
5. Open Ended Survey Questions:
   a. Preunit: What motivates you to learn new concepts? Explain.
   b. Postunit: With DNA, what motivated or excited you about learning? . Explain.

6. Postunit only: In what ways were the activities and lessons on DNA effective in helping you learn? Explain.
7. Postunit only: What instruction and activities need to be improved to help you learn? Explain how you think these should be changed and how the changes would help you learn.
8. Postunit only: If you scored yourself as a disagree or strongly disagree for any question 1-4, please explain why you scored yourself in that category.

Treatment Unit 1 Pre and Postunit Survey Questions: Gene Expression & Mutation

This survey is for the purpose of gaining student feedback in biology. This survey is completely voluntary. If you are not comfortable answering any question you are welcome to stop at any time. Your participation/nonparticipation in this survey will not affect your grade or class standing.

Rank yourself on a scale of 1-5, with 5 being best, for each of the following:

5	4	3	2	1
Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree

1. _____ I feel/felt confident in my understanding of protein synthesis
2. _____ I feel/felt confident in my understanding of mutation
3. _____ I feel/felt motivated to learn about protein synthesis
4. _____ I feel/felt motivated to learn about mutation
5. _____ I feel/felt I can apply my understanding of protein synthesis and mutation to real world scenarios and problems
6. Open Ended Survey Questions:
   a. Preunit: What motivates you to learn new concepts in biology?

b. Postunit: With protein synthesis and mutation, what motivated and excited you about learning?

7. Postunit only: Did the case study on human genetic disorders help you better understand protein synthesis and mutation? Explain.
8. Postunit only: In what ways were the activities and lessons on protein synthesis and mutation effective in helping you learn?
9. Postunit only: Was the case study on human genetic dissorders motivating and/or engaging? Explain.
10. Postunit only: What instruction and activities need to be improved to help you learn? Explain how you think these should be changed and how the changes would help you learn.
11. Postunit only: If you scored yourself as a disagree or strongly disagree for any question 1-4, please explain why you scored yourself in that category.

<u>Treatment Unit 2 Pre and Postunit Survey Questions: Natural Selection</u>

This survey is for the purpose of gaining student feedback in biology. This survey is completely voluntary. If you are not comfortable answering any question you are welcome to stop at any time. Your participation/nonparticipation in this survey will not affect your grade or class standing.

Rank yourself on a scale of 1-5, with 5 being best, for each of the following:

5	4	3	2	1
Strongly Agree	Agree	Neither Agree or Disagree	Disagree	Strongly Disagree

1. _____ I feel/felt confident in my understanding of natural selection
2. _____ I feel/felt motivated to learn about natural selection

3. _____ I feel/felt I can apply my understanding of natural selection to real world scenarios and problems
4. Open Ended Survey Questions:
    a. Preunit: What motivates you to learn new concepts in biology?
    b. Postunit: With natural selection, what motivated and excited you about learning?
5. Postunit only: Did the case study on antibiotic resistance help you better understand natural selection? Explain.
6. Postunit only: In what ways were the activities and lessons on natural selection effective in helping you learn?
7. Postunit only: Was the case study on antibiotic resistance motivating and/or engaging? Explain.
8. Postunit only: What instruction and activities need to be improved to help you learn? Explain how you think these should be changed and how the changes would help you learn.
9. Postunit only: If you scored yourself as a disagree or strongly disagree for any question 1-4, please explain why you scored yourself in that category.

APPENDIX H

STUDENT ASSESSMENT QUESTIONS

<u>Nontreatment Pre and Postunit Assessment Questions: DNA</u>

1. Diagram and explain the structure and function of DNA.
2. Diagram and explain the process and purpose of DNA replication.
3. With your understanding of DNA structure and replication explain how DNA remains stable to allow genes to be passed from one generation to the next.
4. Explain how scientists know DNA is the molecule of heredity using scientific and experimental evidence.

DNA Scenario: If you have ever been to the doctor or dentist and had X-rays taken you have likely worn a lead apron. Though at the time of Rosalind Franklin, we did not understand the effects of radiation, such as X-rays on humans, we have since learned that radiation can cause a change in the DNA of organisms. Therefore, radiology technicians ensure your safety by having you put on a lead apron to protect your reproductive organs from radiation exposure.

5. Explain how changes in your DNA due to radiation would affect you versus your future offspring versus using your understanding of DNA structure and

replication.

Treatment Unit 1 Pre and Postunit Assessment Questions: Gene Expression & Mutation

1. Explain the process of making organisms making proteins, including both transcription and translation.

Prokaryote organisms (bacteria) have higher rate of mutation than eukaryote organisms (plants & animals).

2. Explain what it means for an organism to have a mutation.
3. Explain how having a high rate of mutation may benefit prokaryote organisms compared to the benefit of lower mutation rates of eukaryotes.

Genetic Disorder Scenario: Huntington's disease is a dominant gene mutation that causes neural degeneration in people around 40 years old. Huntington's disease is not all that common, but often people who have the disease have already had children by the time they learn of their genetic disorder. With increases in genetic testing it is now possible for people with a family history of Huntington's disease to find out if they have the disease or not. While it is not fully known how Huntington's disease affects people, we do know that a mutation in the gene for this disease causes extra copies of the amino acid glutamine, which in turn causes cell death in nerve cells.

4. Explain how a mutation could result in extra copies of the amino acid glutamine.
5. Based on what you know about Huntington's disease, if you were a person with a family history of Huntington's disease would you undergo genetic testing to find out if you have the disease when you are young? Explain why or why not.

Treatment Unit 2 Pre and Postunit Assessment Questions: Natural Selection

1. Explain the concept of evolution through natural selection, including the role of DNA and mutations in evolution.
2. Explain how scientists know natural selection occurs in nature using scientific and experimental evidence.

Natural Selection Scenario:

Malaria is a disease of global concern caused by *Plasmodium*, a microorganism that lives in the guts of mosquitoes. Malaria primarily affects people living in tropical regions, those near the equator, where temperatures are warm and wet. Female mosquitoes need blood to be able to survive and pass their genes on to the next generation. When a female mosquito bites a human she first spits an anesthetic into the site of the bite to numb her victim, and if she contains *Plasmodium* she passes this malaria causing microorganism into the human. Once in the human body, *Plasmodium* grows, develops, and reproduces in the red blood cells of the human. As a result the red blood cells lyse, or burst open ultimately causing death due to lack of oxygen carrying red blood cells (a form of anemia).

In tropical regions where malaria has plagued people for thousands of years, something interesting has occurred. Humans who are heterozygous for the gene that causes sickle cell disease, red blood cells shaped like the angel of death's sickle, have increased resistance to malaria compared with homozygous dominant (2 regular red blood cell genes) and homozygous recessive (2 mutant sickle shaped red blood cell genes). In addition, individuals who have both copies of the recessive allele (gene) are considered to have sickle cell disease, or sickle cell anemia, and often have extreme challenges getting oxygen to all their cells/organs and die much earlier in life. Luckily new medical advances are helping prolong the life of sickle cell individuals, but both sickle cell disease and malaria cause death in people.

3. Based on you understanding of natural selection, explain why the sickle cell mutant gene has survived in human populations even though it causes sickness and early death in people with sickle cell disease.
4. There are many people in America who have sickle cell disease, yet malaria is not a concern in the United States. Explain why sickle cell disease would show up in U.S. citizens whose families have lived here for many generations.
5. If you, the amazing and super rich scientist, developed a cure for malaria, what do you think would be the effect on the sickle cell gene in humans? In you answer, be sure to explain why you think this effect would occur using your understanding of natural selection.

APPENDIX I

TEACHER REFLECTION PROMPTS

Reflections Prompts Following Interviews

Following a review of documentation taken during the interview process I answered the following questions regarding student interviews.

1. What content and application did students seem to have a good understanding of content understanding? Explain.
2. What areas of content and application did student struggle with, and why did they struggle? Explain.
3. What areas of instruction seemed to be effective in helping students with higher-order thinking? Explain.
4. What did students attribute their motivation to learn with, and what was the reason behind their motivation? Explain
5. What would I do in the future to improve instruction? Explain.

(See additions of higher-order thinking and motivation)

General Weekly Reflection Prompts

1. What activities and lessons seemed to be effective with student content understanding and motivation this week? Why were these effective?

2. What activities and lessons were not as effective and what would I do in the future to make improvements? Why were these not as effective?
3. Did problem-solving case studies seem to help student understand and apply content using higher-order thinking skills? Explain how this was or was not evident.
4. Did problem-solving case studies seem to motivate students in their learning this week? Explain how this was or was not evident.
5. Did the use of problem-solving case studies motivate me in my teaching, or make me feel effective in my teaching practice? Explain how this was evident or not evident.
6. Were there any ah-ha moments this week? If so, explain.

APPENDIX J

TEACHER FIELD OBSERVATION

Teacher Field Observations

The following is the observation guide used on an ongoing basis during this capstone project implementation. Observational data was collected and recorded on a daily basis as a record of direct observations of student engagement and motivation, in addition to, overall teacher feeling of lesson effectiveness with individual students. A score was given to each individual student using a scale of 10, with 10 being best or most amount of engagement/motivation observed from individual students. Teacher effectiveness per student was also recorded on a 10 point scale to indicate teacher effectiveness with individuals, with 10 being best. Finally, an overall student engagement/motivation and teacher effectiveness score was awarded by averaging the above category score. Additional daily teacher comments were added as needed.

Student	Student Engagement/Motivation		Observation
	Score	Phase of Class & Activity	
Insert Student Names (1 per line)			
OVERALL Average Score & General Class Observations			