

ASSESSING THE NEXT GENERATION SCIENCE STANDARDS AND ITS  
EFFECTS ON STUDENT AND TEACHER LEARNING

by

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## TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND .....	1
2. CONCEPTUAL FRAMEWORK.....	2
3. METHODOLOGY .....	7
4. DATA AND ANALYSIS .....	12
5. INTERPRETATION.....	20
6. VALUE.....	22
REFERENCES CITED.....	26
APPENDICES .....	29
APPENDIX A MSU Project Exemption .....	30
APPENDIX B NGSS Science and Engineering Practices and Cross Cutting Concepts Handout .....	32
APPENDIX C NGSS Assessments .....	36
APPENDIX D Pre and Post NGSS Student Confidence Survey.....	43
APPENDIX E Pre and Post NGSS Teacher Confidence Survey .....	46
APPENDIX F Interview Questions .....	49

LIST OF TABLES

1. Assessment Triangulation Matrix .....12

## LIST OF FIGURES

1. Mean Crosscutting Concept Rubric Scores of the Pre-Treatment and Treatment Assessments .....	13
2. Mean Science and Engineering Practice Rubric Scores of the Pre-Treatment and Treatment Assessments.....	14
3. Mean Disciplinary Core Idea Rubric Scores of the Pre-Treatment and Treatment Assessments .....	15
4. Mean Rubric Scores of the Pre Treatment and Post Treatment Crosscutting Concept Survey .....	16
5. Pre & Post Student Confidence Survey results on Students' Confidence in Their Abilities Using the Science and Engineering Practices .....	18

## ABSTRACT

Science education is at a crucial time, when states and school districts are considering aligning their standards with the Next Generation Science Standards. The purpose of this study was to investigate the effects of the standards on student and teacher learning. Students were given Next Generation Science Standards aligned assessments and averaged together using a rubric. The results showed that students improved in their ability to identify and use the Next Generation Science Standards Science and Engineering Practices along with the Crosscutting Concepts. However, no significant gains were made in the content areas. Through student interviews, students expressed an enjoyment of learning the Practices and Crosscutting Concepts.

## INTRODUCTION AND BACKGROUND

Located in central Montana, Great Falls High School is an AA school, the largest classification designation from the state. With an enrollment of 1342 students in 2015, Great Falls High (GFH) had a 12.7 student to teacher ratio. Forty percent of the students received free and reduced lunch, which was higher than the state average of 36.6%. At the time of this study at GFH, 79% of the students were white, 14% were Native American, three percent were Hispanic, two percent were black, one percent were Pacific Islanders, and the remaining one percent were Asian (National Center for Education Statistics, 2015). Due to its low-income population, Great Falls High has been the recipient of numerous grants that have assisted the school and teachers to keep student achievement high.

I was a graduate of Great Falls High in 2004 and I returned to my hometown to teach biology in 2015. The science department at GFH was beginning the initial steps of a science curricular review. Montana was one of the lead states that helped in the creation of the *Next Generation Science Standards Framework*, which “describes a vision of what it means to be proficient in science; it rests on a view of science as both a body of knowledge and an evidence-based, model and theory building enterprise that continually extends, refines, and revises knowledge” (NGSS Lead States, 2013). Tom Cubbage, president of the Montana Science Teachers Association, explained that the Montana legislature will likely adopt new state science academic standards based on NGSS within the next few years (personal conversation, November 5, 2015). Great Falls Public School District has been undergoing the process of writing new district standards based on NGSS and I was asked to be a part of the curriculum review.

The year before I came to Great Falls High, I participated in a training program for NGSS called The Montana Partnership with Regions for Excellence in STEM. It was through this project and other courses that I discovered the significant impact of NGSS on myself, as an educator, and my students. Since then I have been implementing aspects of NGSS into my lessons on a regular basis. However, I did so without any formal instruction about the three-dimensions that are woven throughout NGSS: the disciplinary core ideas, the science and engineering practices, and the crosscutting concepts (NGSS Lead States, 2013). While student engagement is high during NGSS aligned lessons, I was unsure if students were actually learning more through this new method of instruction.

These three factors lead to my chosen research focus: my training in NGSS, my school district's science curricular review, and my desire to see the impact NGSS is having on my student's learning, in addition to my own. Through this I came to my research question: *What are the effects of three-dimensional assessments on student learning following explicit instruction of the Next Generation Science Standards science and engineering practices and crosscutting concepts?*

## CONCEPTUAL FRAMEWORK

With a simple glance into media and politics, there is a general consensus that the United States needs more students interested in science, technology, engineering and math (STEM). Former governor of Michigan, John Engler (2012), wrote an article for *U.S. News and World Report* arguing that "STEM education is the key to the U.S.'s economic future" (para. 1). With the increasing emphasis on global competitiveness and

society's drive for economic prosperity, fulfilling STEM jobs have come to the forefront of policy makers' agendas. Legislative action has been passed to bolster the importance of such changes in education. For instance, the 2007 America COMPETES Act authorized increased expenditures for improving mathematics and science education.

The science and math test scores of students in the U.S. have been lagging behind students in Asia. China is seen as our global economic rival, and our uncompetitive scores are viewed as a bad omen for the success of our nation. Some researchers suggest that the structural design of U.S. high schools could be to blame. One problem is the linear aspect of curricular design. Students learn information for a test, take said test, and then very little of the learning is retained after the final grade is given. Learning should be structured to galvanize students toward STEM areas because they are excited about science and in turn their motivation will be in the actual work, rather than the grades they receive (Jensen, 2012).

The National Research Council (2012) set out to solve that problem by creating *A Framework for K-12 Science Education*. The Next Generation Science Standards (NGSS) were then drafted through a state-led process that used the *Framework* as the foundation (NGSS Lead States, 2013). The *Framework* centers on a growing body of research concerning the teaching and learning of science, which is designed around three major dimensions of instruction. The dimensions include Science and Engineering Practices, Crosscutting Concepts and the Disciplinary Core Ideas. These dimensions will be integrated throughout the standards of science and engineering.

The intention of the *Framework* is to engage students with opportunities to learn how science is truly conducted and deepen scientific learning within certain areas. The

phrase, *a mile wide and an inch deep* is often used to criticize the U.S. science curricula. This refers to the fact that many state standards are long lists of exhaustive and disconnected facts, which when taught to students, leaves them estranged from an understanding of how science truly works (National Research Council, 2012). However, through the *Framework* and its three dimensions, children can build upon their previous knowledge, deepen their understanding, and engage in scientific inquiry throughout their K-12 education.

There is a strained dynamic within the priorities of science teaching. Should teachers concentrate on developing knowledge in the science content or should the emphasis be placed on the scientific practices? If students are solely focused on content, then they may lose the understanding of how science works and be left with the “impression that science is simply a body of isolated facts” (National Research Council, 2012, p. 41). By training students in the science and engineering practices, the *Framework’s* goal is to create young minds with a deep understanding of the process of conducting science.

Recently many states have adopted the Common Core standards, which have a strong emphasis in mathematics and language arts. These standards, however, are lacking comparable documents in the sciences (National Research Council, 2012). Since the official release of the Next Generation Science Standards in April 2013, only thirteen states have adopted these standards (“NGSS Adoption Map,” n.d.). Due to its novelty there is little research available regarding how the new standards are affecting student learning and attitudes toward science. The *Framework* and NGSS were written with significant time spent in examining the important areas of concern. The National

Research Council committee based its study on a vast body of research. Growing from that research was the understanding that meaningful learning in STEM depends on the three major dimensions as defined by the National Research Council (2012, p.2). These dimensions are

- Scientific and Engineering Practices
- Crosscutting Concepts that unify the study of science and engineering through their common application across fields
- Disciplinary Core Ideas in four areas: physical science, life science, earth and space sciences; and engineering, technology, and application of science.

Integrating the three dimensions is still a largely unexplored area that is ready for pioneers to begin the research (National Research Council, 2012). The National Science Teacher Association (NSTA) provides information on how to design units and lessons using the NGSS. Their suggestion is to work backwards, first designating one or two performance expectations that will show the competency of students' understanding of the content, practices, and concepts being studied. From that point, teachers should pick scientific phenomenon that allow students to investigate the core idea. Once the phenomenon has been identified, the teacher should choose practices that will allow students to make discoveries and innovations regarding the phenomenon. At the end of this process, the teacher should embrace one crosscutting concept that is paramount to the content. In an effort to show students how ideas in science are interconnected regardless of the subject matter, the crosscutting concept is integrated all through the lesson or unit (NSTA, 2014).

Teachers need a way to monitor the learning of their students, and so assessments that align with the NGSS must be created. In the book, *Developing Assessments for the Next Generation Science Standards*, the authors lay out how teachers, schools, and districts may go about designing assessments (Pellegrino, Wilson, Koenig, & Beatty, 2014). They made two conclusions about assessments aligned with NGSS. First, the assessments will require multiple components in order to adequately cover the three dimensions. Second, they should increase in complexity in order to assess where students lie along a continuum of development. Due to the vigor of the standards, classroom instruction and assessment should also be robust. Lessons should include many forms of observation, activities, and components in order to capture the three dimensions of NGSS.

In order to assess the Performance Expectations, there are three main components that should be kept in mind during the creation of assessments. First, the assessments need to consist of multiple components in an effort to show the connectivity between multiple practices and concepts. Second, assessments should show the progression of the students and where they fall on a continuum of learning. And third, an “interpretive system” that will help teachers decide on the next steps for instructions for their students (Pellegrino et al., 2014, p. 130).

There are many challenges ahead regarding NGSS, not only in the instruction of students, but the ways in which teachers will assess these standards. But Dozier (2015) offers words of wisdom and comfort in her article *Strategies for Assessing Student Understanding in the NGSS Classroom*. Her advice to educators is to start small and use the lessons and assessments they already teach, incorporating some of the aspects of

NGSS into both the lesson and the assessment. She, like others, puts emphasis on the importance of using more than one question in order to gain the full picture of how all three dimensions are incorporated into the students' learning. Although multiple Science and Engineering Practices are oftentimes used in a single science lesson, Dozier says to just pick one practice and to focus on that during discussions and the final analysis of the activity. The main goal of NGSS aligned assessment is "to find ways to elicit responses that allow [teachers] to see inside students' thinking" (Dozier, 2015).

The NSTA sums up why science education in the United States is at a critical point for the need of new standards, a new way of teaching science, and a way to assess those standards. It's all about less memorizing and more sense making, which allows teachers to take content deeper, giving students the time to make scientific discoveries on their own and see science truly in action (NSTA, 2014). With the new *Framework* and Next Generation Science Standards, science education is at an exciting point, where students will be able to make rich and lasting connections that combine both scientific knowledge and scientific practices. This will bring students to the next generation of science education in this country.

## METHODOLOGY

This study was comprised of 31 students enrolled in two periods of biology 1-2, the required science course for sophomores at Great Falls High School. I only chose biology 1-2 because the Next Generation Science Standards (NGSS) only include standards specifically for high school life science and the Disciplinary Core Ideas do not extend beyond the scope of these courses. Seventy-two percent of the class is comprised of white students and 26 percent are Native American. The two classes are a mixture of a

typical sophomore class, including high achieving students and those who need additional support. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Since the beginning of the 2015-2016 school year, students were engaged in inquiry-based lessons that taught the biology 1-2 curriculum. In addition, students in this class maintained a science notebook, one important feature of NGSS. A large emphasis in the course was placed on the importance and benefits of using science notebooks. My background provided me with the skills to teach the students lessons that were based in the NGSS, however prior to the treatment, no explicit instruction was given regarding the NGSS Science and Engineering Practices and the Crosscutting Concepts.

At the end of January, following first semester finals, lessons were designed to teach students about the NGSS Science and Engineering Practices (SEP) and the Cross Cutting Concepts (CCC). Students were given SEP and CCC handouts that they were to keep as references in their science notebooks. This handout was referenced throughout the treatment period as students were conducting investigations and participating in the assessments (Appendix B). During the first week of the treatment period students took brief notes on the NGSS and participated in a few activities to demonstrate the SEP and the CCC.

Following this initial week of instruction on NGSS, classroom activities resumed as normal, however the design of my classroom lessons and activities became more focused. The units of instruction during the treatment period were centered around the topics of population genetics and evolution. Each lesson was geared towards meeting one

of the NGSS Performance Expectations and I generated a variety of assessments to meet those Performance Expectations. The assessments varied from activity to activity, but a basic rubric was used to score the student's abilities at identifying the SEP, CCC and the Disciplinary Core Ideas (DCI).

The first assessment, the Galapagos assessment, followed a multiday study of the island finches. Students were asked to make and defend a claim, based on evidence, explaining why the finches had a wide range of variations in beak morphology. The second assessment, the whale evolution assessment, was given after students investigated findings from other scientists in order to determine the closest ancestors to whales. Students were asked, "In 3-4 sentences, communicate the findings of your evidence that aided you in determining the common ancestor of whales." The third assessment, the natural selection assessment, followed a lesson and a lab modeling natural selection. Students were asked, "What are the four conditions necessary for natural selection to occur? Describe how this model met each of the four conditions. And did natural selection occur? What is your evidence?" The fourth assessment asked students to determine which lizard was the most biologically fit based on the provided data. The final assessment followed a lab activity where students investigate the change in genes within a population undergoing natural selection. Students were asked to "write a statement that summarizes how the genetic makeup of a population changes with changes in the environment." A breakdown of each of these assessments can be seen in Appendix C.

Additionally, rubrics were created for each Performance Expectations that went along with the individual assessments (Appendix C). The rubrics typically addressed three areas of assessment: the actual Performance Expectation or DCI, the ability to

identify the Science and Engineering Practice, and the ability to identify the Crosscutting Concept. The Next Generation Science Standards lists out which specific SEP and CCC are associated with each Performance Expectation so those became the ideal answers when scoring using the rubrics (NGSS Lead States, 2013). If a student identified the SEP and/or CCC that was designated by NGSS, they scored a 2 on the rubric. However, there are a variety of other acceptable responses that I would accept, therefore the rubric reflected additional suitable responses as scoring a 1. Students earned a 0 if they incorrectly identified an SEP or CCC or if they did not answer the question. These changes were made to the scoring rubric following my Pre-Treatment assessment.

Both quantitative and qualitative data was collected from a variety of sources. Before the treatment even began, I gave my first assessment based on the NGSS Performance Expectation in an effort to understand how I would complete my data collection process. This assessment took place during the first semester unit over cellular anatomy. Results from the initial assessment provided me with insights as to how I should score and administer future assessments. The data collected was used as the Pre-Treatment Assessment (Appendix C) which was compared against the Treatment Assessments, 31 students participated in the Pre-Treatment Assessment.

Before the treatment period began, 24 students took the Pre NGSS Student Confidence Survey to measure student confidence in using the Science and Engineering Practices and they were tested on their ability to identify the Crosscutting Concepts within biology themes (Appendix D).

I also assessed myself through a Pre NGSS Teacher Confidence Survey to analyze my own personal confidence level in teaching the SEP and CCC to my students (Appendix E).

At the end of the treatment period the same confidence surveys were administered to 23 students, which compared any changes regarding the student's confidence levels regarding the SEP and their ability to identify the CCC. The data was analyzed for normalized gains.

In regards to the teacher confidence survey, these results were obtained only to provide myself with evidence of my personal conceptual change throughout the classroom research.

Throughout the treatment period, from February to April, five NGSS Assessments were given and scored using rubrics (Appendix C). The results of these assessments were organized into bar charts in order to analyze the number of students who able to identify the SEP and CCC within the regular classroom activities. The mean scores of these assessments were compared to the Pre-Treatment Assessment for analysis. Additionally, the results were structured to determine if students were able to pick out the designated NGSS SEP and CCC, earning a score of 2, or to compare those results to students who picked out SEP and CCC that were acceptable but not NGSS designated, earning a score of 1. Over the course of the treatment, the number of students who took the Treatment Assessments varied greatly due to absences, transfers, and drop outs. Therefore, student scores were used to find the mean of each rubric score. For the CCC Assessments, 55 student assessments were scored; for the SEP Assessments, 132 student

assessments were scored; and for the DCI Assessments, 155 student assessments were scored.

Additionally, I conducted student interviews following each assessment with two or three students using the Interview Questions in an effort to gain more descriptive data (Appendix F). The responses to interview questions provided additional qualitative data to support the findings of the quantitative data.

An overview of the instruments used during this study, along with their period of administration, can be seen in the Assessment Triangulation Matrix (Table 1).

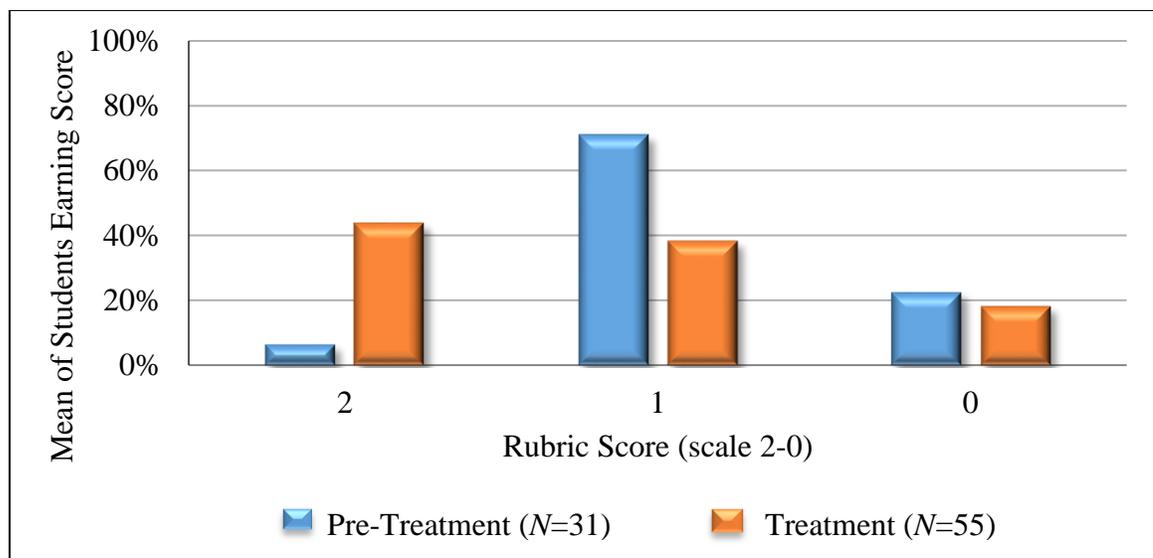
Table 1  
*Assessment Triangulation Matrix*

Time Frame	Instruments
<i>Pre-Treatment</i>	Pre-Treatment Assessment
	Pre NGSS Student Confidence Survey on the SEP and CCC
	Pre NGSS Teacher Confidence Survey on the SEP and CCC
<i>Treatment Period</i>	NGSS Treatment Assessments analyzed using rubrics
	Student Interviews
<i>Post-Treatment</i>	Post NGSS Student Confidence Survey on the SEP and CCC
	Post NGSS Teacher Confidence Survey on the SEP and CCC

## DATA ANALYSIS

A comparison of the mean scores of the Pre-Treatment ( $N=31$ ) and Treatment ( $N=55$ ) Next Generation Assessments indicated a 38% increase in the students' ability to correctly identify the NGSS Crosscutting Concepts (Figure 1). During the Galapagos Assessment, 68% of students correctly identified *cause & effect* as the Crosscutting Concept (CCC), *cause & effect* was the appropriate CCC identified by NGSS for the

particular standard being assessed ( $N=32$ ). However, during the Whale Evolution Assessment, only 17% of students were successful at identifying the CCC of *patterns* ( $N=23$ ). When asked if they thought learning about the CCC was difficult or easy, one student thought it was “easy because it is kind of like common sense.” However, another student disagreed, stating, “I honestly couldn’t remember what they were – but I am pretty sure I was zoning out that day.”



*Figure 1.* Mean Crosscutting Concept rubric scores of the Pre-Treatment and Treatment Assessments. *Note.* 2=correct identification, 1=other acceptable identification, 0=unacceptable identification or left unanswered.

The mean results of the Pre-Treatment ( $N=31$ ) and Treatment ( $N=132$ ) Next Generation Assessments for the Science and Engineering Practices showed an increase of 16% (Figure 2). Students performed best on the Fitness Assessment when asked to use the practice *interpreting data*, 71% correctly interpreting the evidence provided ( $N=31$ ). One student said, “Lizard B would be considered the ‘most fit’ because she has sexually reproduced many times, therefore passing on her good traits, like the ability to reproduce.” The Whale Evolution Assessment was the lowest scoring assessment for the

use and identification of the practices, with only 13% of students indicated that they used the science practice of *obtaining, evaluating, and communicating information* ( $N=23$ ).

When asked how they felt about using and identifying the SEP most of the responses were positive. One student shared that “it gives you an idea of what you’re doing, like the reason why we are doing it in class” and another said he “enjoyed doing the labs to help [him] better understand these practices but [without] reviewing them.”

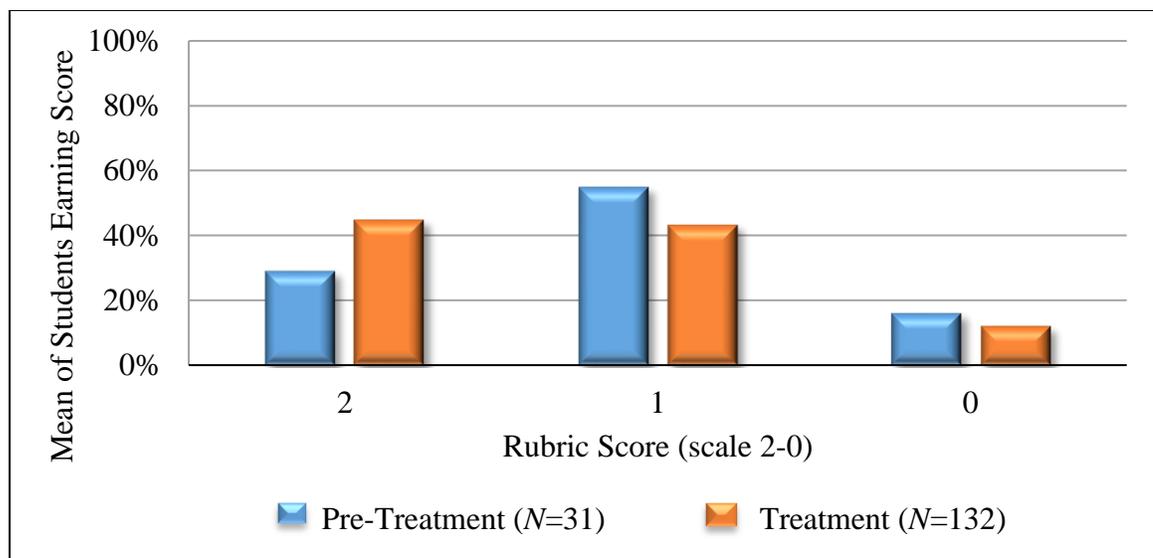
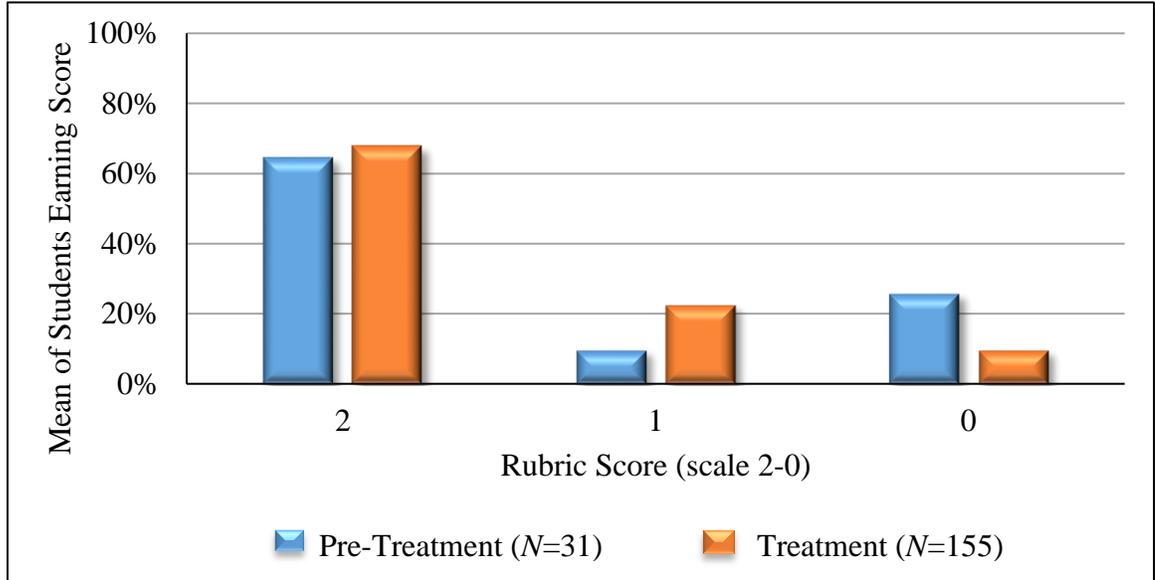


Figure 2. Mean Science and Engineering Practice rubric scores of the Pre-Treatment and Treatment Assessments. Note. 2=correct identification, 1=other acceptable identification, 0=unacceptable identification or left unanswered.

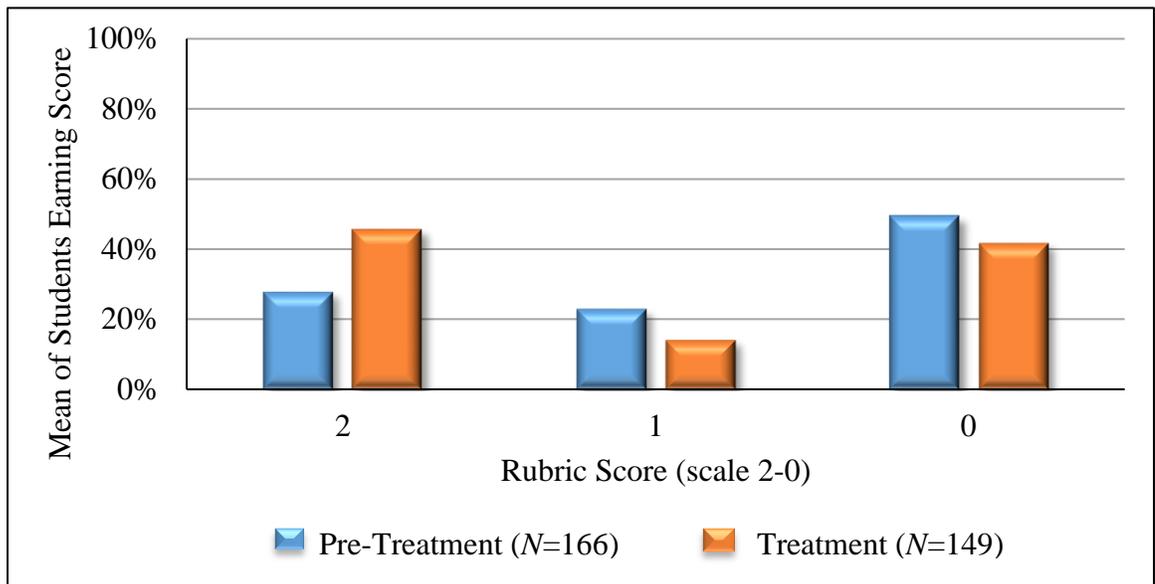
However, when assessing the Disciplinary Core Ideas the mean Treatment ( $N=155$ ) scores of the DCI only increased by 3%. The Pre-treatment ( $N=31$ ) DCI scores were high at 65%, (Figure 3). The lowest scoring assessment was the Natural Selection and Genes Assessment. Only 39% of students scored a 2 when asked to write a statement that summarizes how the genetic makeup of a population changes with changes in the environment ( $N=23$ ). “When change is needed the population will make that change because of the need to survive” was a response that earned a rubric score of 1. The

student did not leave the question unanswered, however the statement did not accurately represent the process of natural selection. Twenty-six percent of students did not attempt to answer this assessment question ( $N=23$ ).



*Figure 3.* Mean Disciplinary Core Idea rubric scores of the Pre-Treatment and Treatment Assessments. *Note.* 2=correct identification, 1=other acceptable identification, 0=unacceptable identification or left unanswered.

At the end of the treatment period, students retook the Crosscutting Concept Survey that asked them to identify the CCC that best fit the scientific phenomena described. The results of the Pre Treatment ( $N=166$ ) and Post Treatment ( $N=149$ ) scores can be seen in Figure 4. If a student selected a CCC that was identified by NGSS, they earned a score of 2 and other acceptable answers were given a 1. There was an 18% increase in students able to identify the correct CCC.



*Figure 4.* Mean rubric scores of the Pre Treatment and Post Treatment Crosscutting Concept Survey. *Note.* 2=correct identification, 1=other acceptable identification, 0=unacceptable identification or left unanswered.

The results of Pre and Post Student Confidence Survey can be seen in Figure 5. Student confidence increased when asked about using the Practices *obtaining, evaluating, and communicating information; arguing from evidence; constructing explanations; and analyzing data*. When interviewed, students were asked to respond to the areas where there was an increase in their confidence. “We spent time learning this stuff and knowing what something [is] will always make me feel better about a topic” was one of many responses that shared the same sentiment. When asked specifically about the practice *obtaining, evaluating, and communicating information* one student shared, “I enjoyed the project and learning about the specific genetic disorder I was supposed to research. Learning about an individual topic makes it stick in your brain so much more, you know?” Regarding *analyzing data*, one student “learned more ways to do [the practice]” and so her confidence increased. Another student shared that her increase came from the

fact that she “got better at using the computer” to complete her analyses. “At the beginning of the semester I was new to the class and didn’t feel as comfortable because I didn’t know everyone. But as time went on I became more comfortable and then I felt like I could be myself and that’s why my confidence increased” in the area of *arguing from evidence*.

In the Pre and Post Student Confidence Survey, student confidence decreased when asked about using the Practices *using mathematical thinking; planning and carrying out investigations; using models; and asking questions*. There were a variety of responses in regards to why their confidence decreased. “I probably just didn’t answer it honestly” shared one and another replied “for all of them I really just chose a random mark. But I do agree with a lot of my marks I made. I went down [in confidence] because as we were learning all of it, I realized there’s a lot more to know.” Another student shared his decrease in confidence was because “it got confusing, the deeper we got, the harder it got.” When asked specifically about *using mathematical thinking*, the area of the greatest decrease at -18%, many students shared a similar attitude. “I feel like it went down because I’m sucking at math right now,” “I became less confident in mathematical thinking because I realized math is where I struggle the most,” and simply put “#badatmath.” Regarding decreases in *planning and carrying out investigations*, some responses included “my confidence decreased because my plan does not always work out fully” and another said “I’m not good at planning.” Students responded to their decreases in confidence *using models* sharing, “After doing some models I realized it’s a little harder to analyze than I thought originally” and “I realized using some tools aren’t easy to use.” When asked why they marked themselves down in the area of *asking questions*,

one student shared “I am a quiet student. I feel more rewarded figuring it out myself, instead of asking questions in class.”

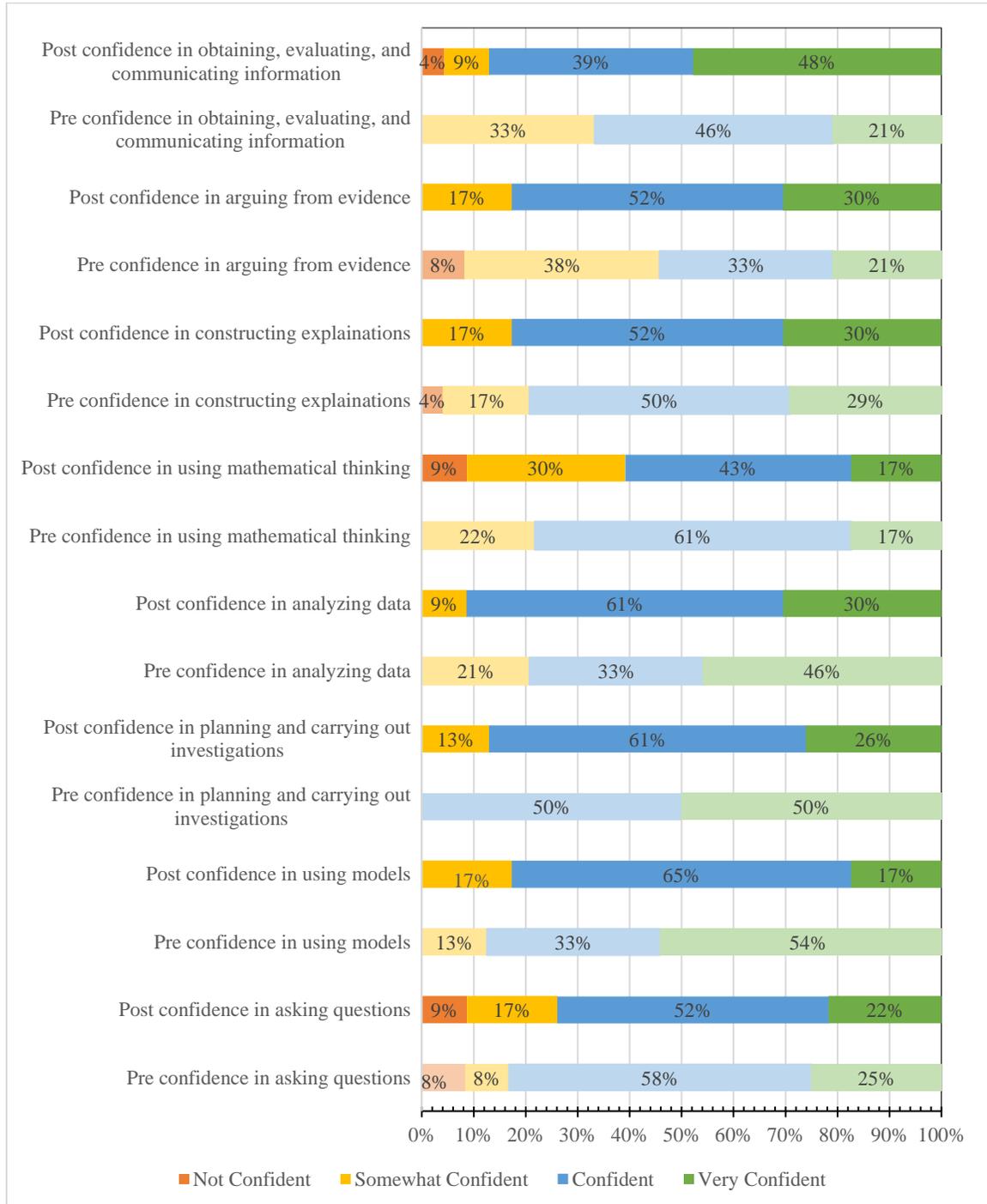


Figure 5. Pre Student Confidence Survey (N=24) & Post Student Confidence Survey (N=23) results on students' confidence in their abilities using the Science and Engineering Practices.

The final part of the interview asked students about their attitudes and feelings toward the learning that occurred during the treatment period. There were a variety of responses and feelings about it. When asked if he enjoyed the process, one student said, “No, I didn’t because I don’t like learning new ways to do something out of nowhere really” referring to the fact that the treatment began in the middle of February instead of beginning the school year. Other students shared that they did not enjoy it because “it was kind of hard and boring,” “they confused me,” and “I did not enjoy learning about the practices and cross cutting concepts because I don’t know which one to choose.” Other students had a different perspective sharing “I found them easy after I got a good understanding of them.” “I thought it was hard to learn the CCC but identifying the Practices was an easy common sense type of deal.” One student shared he thought they made learning science easier because “In some ways I found it easier to finish some projects because it helped me decide how to look at the problem.” And another responded, “It was relatively easy. We [use the Practices] in everyday life. All that was changed was I realized we were using them and they had a name.”

When asked if they enjoyed the activities and assessments 72% of responses were affirmative ( $N=18$ ). “Yes, I enjoyed learning about the practices and cross cutting concepts because it was taught in a great, understandable way.” “I did enjoy learning about them because it opens up a whole new variety of methods to learn and understand science concepts.” “I enjoyed it because it was fun and we got to spend a week doing random stuff.” “I feel like the concepts are useful throughout this class and some of the experiments we did were fun, so I guess you could say I had fun learning about the concepts.”

## INTERPRETATION

This study has led me to a number of different conclusions regarding how the assessment of the Next Generation Science Standards positively affects students learning. First off, it is possible to assess and score students on their ability to use the Science and Engineering Practices as well as teaching students to identify appropriate Crosscutting Concepts in science phenomena. Overall, students experienced an increase in the science skills that were measured during the treatment period and importantly the number of zero scores decreased.

When identifying the CCC, student abilities increased by 38%. As one student stated, they found that they were easy to identify due to the fact it was common sense, some students expressed having this innate ability. From my personal knowledge of my students and their abilities, the students who struggled with the CCC also struggle with seeing the big picture in many aspects of life. It is possible this was a factor.

When using the SEP, students experienced a growth of only 16%. The largest struggle seemed to come from the fact that students would pick an acceptable SEP, but it was not the one distinguished by the NGSS Performance Expectation, and so those students earned a *1* on the rubric scale. Students did express a lot of enjoyment out of using the Practices in class. Engagement was very high during many of our activities and many expressed that they saw the importance of learning and using these skills. During the student interview, it was shared that the Practices led them to being more successful in the actual assessment itself.

However, there was not a significant increase in the assessment of the content, or the Disciplinary Core Ideas. One reason for this could be during the course of the school

year, I used NGSS to guide my lessons, labs and assessments. Other than providing them explicit instruction in the NGSS Practices and CCC, nothing changed in the way we went about learning in class. At the start of the treatment, students were already performing at a higher level for the DCI assessment, compared to their scores in the SEP and CCC. Another factor could be that the Pre-Treatment Assessment was given during the cellular anatomy unit. During the treatment period, students were learning about population genetics and evolution, which are first introduced into the science curriculum at the sophomore level. Prior to high school, students have been exposed cells multiple times throughout their education in our school district, unlike population genetics and evolution.

Regarding student confidence, the results were surprising to me. I was expecting student confidence to go up across the board after being exposed to and using the SEP. However, there were distinct areas of increase as well as decrease. The student interviews were very informative as to why this trend may have occurred. There were a few Practices that we spent more time on during the treatment period. For example, students had a week where they researched and created an infographic on a specific genetic disorder, many students referred to this project as to why their confidence increased in the area of obtaining, evaluating, and communicating information. Also, the large increase in arguing from evidence was likely due to the amount of time we spent investigating the changes in the Galapagos Island finches. Students worked collaboratively to argue their case for why the generations of birds experience change over time.

When student confidence decreased, I relied on my students' honesty in their interviews to explain the reasoning why. Using mathematical thinking experienced the greatest decrease, and many student comments supported this data. Many students shared they have a dislike for math, particularly geometry, and the struggles they had in their math class carried over into their science learning. Another strong reason for the decreases in general was a number of students stated that when they took the Pre-Treatment Survey, they thought they knew what those Practices entailed and that they were confident in their abilities to perform them. However, once instruction on the SEP was underway, a number of them realized how much deeper their understanding of the Practices was compared to their initial assumptions. When those students realized they had a lot to learn about the Practices, their confidence went down. And then of course, some of the students admitted to not taking the surveys seriously and filled out "random marks."

Students expressed that they found learning this way challenging yet enjoyable. The methods and techniques of having students perform the SEP gave them hands on experience and introduced them to a variety of different methods of doing science. Importantly, students made connections from NGSS to what they already do in their daily lives and activities. Providing them with meaningful, authentic learning.

#### VALUE

The results of this action-based classroom research project was of incredible significance to me. The biggest insight I gained was that I am determined to begin my school year with the explicit instruction of NGSS, the Science and Engineering Practices and the Crosscutting Concepts. One student commented that they wished we had started

the year with the instruction they received during the treatment period and I couldn't agree more. A few of my teaching partners have asked if we can work together next year in designing our beginning of the year activities to model some of the activities I did in class during my explicit instruction period.

Another impactful benefit of the study has been my involvement with the district's curriculum review and rewriting of the science standards using NGSS. Next school year I have volunteered to pilot the new science curriculum before the standards are adopted for the 2017-2018 school year. My hope is my experience in writing and assessing the standards will be made useful next school year when the district begins writing the new district science assessments. One question that still remains unanswered to me, is how you can simultaneously assess the DCI along with the SEP and CCC in a standardize testing situation. My assessments were rubric based and assessed the three-dimensions separately. Continued studies should further investigative methods in which to standardize three-dimensional assessments.

After further reflection on my project, one thing I observed was the decrease in the number of zero scores earned from the Treatment Assessments in all three dimensions, an aspect I realized in hindsight would have been interesting to analyze.

The explicit instruction of the SEP and CCC was unique to anything I have ever done before in my teaching career, I was outwardly sharing my teaching methods with the students and making them a part of the teaching process. I think it was a very valuable practice and impactful for students for them to see my thinking when it came to their education. Similarly to the pedagogical reasons why teachers share learner objectives with students, but this explicit instruction took it a step further. I felt like I was providing

my students with a road map of where their science education is going to take them. Not just in biology, but when they go on to chemistry, physics, or geology. The idea that the CCC and SEP will go with them regardless of what science course they take; I hope was impactful. I realized that I was providing them with a guide to their learning.

Keeping a science notebook had been a key aspect of my teaching all year, however I want to incorporate the idea of providing students a roadmap literally in their notebooks. Next year I intend to utilize a science notebook organizational method that the students will insert into the start of each unit. It will be a sheet/insert that includes the components of our district standards, but also the SEP and CCC that will be addressed in the unit. Instead of asking students to choose the best fitting CCC for a unit, I will provide them with that information at the beginning and reinforce it all along the way.

This project also caused me to reflect on my own comfort levels teaching the different SEP and CCC. I realized that I needed to be intentional about including the science practices I am less comfortable with in my lesson plans on a regular basis. I teach what I am most comfortable with and found it difficult to generate lessons that emphasized those areas where I have my own weaknesses, mathematical thinking for example. I also realized that I needed to deepen my own understanding of the CCC of patterns; scale proportional, and quantity; and systems and system models.

I found the importance of the SEP and CCC have on the content of science is very valuable. With NGSS making its way into more and more states and districts, the need for assessments is impending. I have a greater appreciation for those who write assessments, and I now realize the difficulty there is when writing to assess such encompassing standards.

I will certainly continue to improve on my instruction of the SEP and CCC within NGSS. A few valuable things my students taught me was that this kind of learning gets harder before it gets easier, there's a point where students realize how in-depth the science practices can get. But the important thing is they don't give up, they keep working hard, continue to improve and through that process they will be the most successful. I hope that I can motivate and guide them through that important journey.

There were limitations to the study. Throughout the treatment period I had a number of new students join my class as well as a number of students moved or dropped out. My sample size was frequently changing and not all students took the assessments or the Pre and Post Confidence Surveys. Due to the constraints of my school district policies, students had to opt in, instead of opt out of the study, which affected my sample size as well. More data over a larger sample size over a longer period of time may have shown more distinct results. Another limitation was possibly the unit of study. There are a number of different perspectives on the teaching of evolution and there is the possibility that personal beliefs could have affected student's willingness to learn the particular topic and therefor affected the collected data.

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APPENDICES

APPENDIX A  
MSU PROJECT EXEMPTION



**INSTITUTIONAL REVIEW BOARD**  
**For the Protection of Human Subjects**  
**FWA 00000165**

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**MEMORANDUM**

**TO:** Amber Lloyd and John Graves  
**FROM:** Mark Quinn, Chair *Mark Quinn CJ*  
**DATE:** February 2, 2016  
**RE:** "Assessing the Next Generation Science Standards and its Effect on Student and Teacher Learning"  
 [AL020216-EX]

The above research, described in your submission of February 2, 2016, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

APPENDIX B  
NGSS SCIENCE AND ENGINEERING PRACTICES AND CROSS CUTTING  
CONCEPTS HANDOUTS

# Science and Engineering Practices

## Asking questions and defining problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested.

## Developing and using models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations.

## Planning and carrying out investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

## Analyzing and interpreting data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools – including tabulation, graphical interpretation, visualization, and statistical analysis – to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results.

## Using mathematics and computational thinking

In both science and engineering mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations, solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships.

## Constructing explanations and designing solutions

The end-products of science are explanations and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. Theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories.

## Engaging in argument from evidence

Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem.

## Obtaining, evaluating, and communicating information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually in groups is a critical professional activity.

# Crosscutting Concepts

## Patterns

Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

## Cause and effect

Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

## Scale, proportion, and quantity

In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

## Systems and system models

A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

## Energy and matter

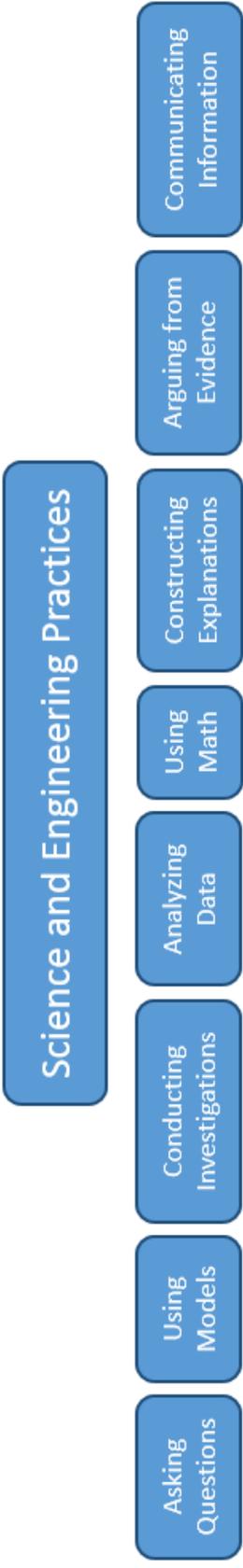
Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

## Structure and function

The way an object is shaped or structured determines many of its properties and functions.

## Stability and change

For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.



**Life Science:  
Disciplinary Core Ideas**



**Crosscutting Concepts**

APPENDIX C  
NGSS ASSESSMENTS

Name of PE	Performance Expectation (PE)		
<i>Assessment MS-LS1-1 is for the pre-treatment data analysis</i>			
<b>MS-LS1-1.</b>	Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.		
<b>Pre Assessment on Cells</b>			
<p><i>During today's lab exploration, provide evidence that living things are made of cells.</i></p> <p><i>Identify one cross-cutting concept that is involved in today's lesson.</i></p> <p><i>What science practice did you use?</i></p>			
<b>Rubric</b>			
Dimensions being assessed	0	1	2
Evidence provided relating to the disciplinary core idea (DCI)	No evidence provided	Provided evidence, but it did not relate to the DCI.	Evidence provided related to the DCI (all living things are made of cells).
NGSS cross-cutting concept (CCC)	No answer or it was not a NGSS CCC	NGSS CCC was identified, however it was incorrect.	Correctly identified the NGSS CCC.
NGSS practice	No answer or it was not a NGSS practice	NGSS practice was identified, however it was incorrect.	Correctly identified the NGSS practice.

Name of PE	Performance Expectation (PE)		
HS-LS3-2.	Make and defend a claim based on evidence that inheritable genetic variations may result from: mutations caused by environmental factors.		
<b>Galapagos Assessment</b>			
<p><i>The Galapagos Islands, located 600 miles from the coast of Ecuador, are a group of geologically young islands, having formed by volcanos 5 million years ago. Today the islands are home to 13 different species of finches found in various combinations. The birds live in diverse habitats. The individual islands themselves vary greatly in size, topography, &amp; height which leads to different plant-life on each of the islands. Larger trees grow at higher elevations, while low islands have mostly cactus, grasses and shrubs. The 13 species of finches in the Galapagos have very different beaks. DNA evidence indicates that the Galapagos finch species are all more related to one another than any one is to a species on the mainland; they all evolved from one ancestral species.</i></p> <p><i>Make and defend a claim, based on evidence, explaining why the finches have a wide range of variations.</i></p> <p><i>Can you identify a cross-cutting concept that is depicted through the phenomenon described above?</i></p> <p><i>What practice did you use in order to answer the first question?</i></p>			
<b>Rubric</b>			
Dimensions being assessed	0	1	2
Made a claim with evidence (relating to the DCI)	No claim or evidence provided	Either claim with no evidence or evidence with no claim.	Provided both a claim & evidence.
NGSS cross-cutting concept (CCC)	No answer or it was not an accepted CCC	NGSS CCC was identified, however it was not the NGSS identified CCC.	Correctly identified the NGSS CCC cause & effect.
NGSS practice	No answer or it was not an accepted practice	NGSS practice was identified, however it was not the NGSS identified practice.	Correctly identified the NGSS practice engaging in argument from evidence.

Name of PE	Performance Expectation (PE)		
HS-LS4-1.	Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.		
<b>Whale Evolution Assessment</b>			
<p><i>[Questions students answered following a Web Quest Lab where they investigated findings from other scientists in order to determine the closest ancestors to whales]</i></p> <p><i>In 3-4 sentences, communicate the findings of your evidence that aided you in determining the common ancestor of whales.</i></p> <p><i>What Science and Engineering Practice was used in today's Whale Web Lab?</i></p> <p><i>What Cross Cutting Concept best fits the concept of evolution?</i></p>			
<b>Rubric</b>			
Dimensions being assessed	0	1	2
Evidence provided supported their final hypothesis (relating to the DCI)	No evidence provided	Evidence did not support their hypothesis, or mis-interpretation of the evidence occurred	Provided supporting evidence for their hypothesis
NGSS cross-cutting concept (CCC)	No answer or it was not an accepted CCC	CCC was identified, however it was not the NGSS identified CCC.	Correctly identified the NGSS CCC.
NGSS practice	No answer or it was not an accepted practice	A practice was identified; however, it was not the NGSS identified practice.	Correctly identified the NGSS practice.

Name of PE	Performance Expectation (PE)		
<b>HS-LS4-2.</b>	Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.		
Conditions of Natural Selection Assessment			
<p><i>What are the four conditions necessary for natural selection to occur?</i></p> <p><i>Describe how this model met each of the four conditions.</i></p> <p><i>Did natural selection occur? What is your evidence?</i></p>			
Rubric			
Dimensions being assessed	0	1	2
Listed the four conditions (relating to the DCI)	No conditions listed	Listed 1-3 of the conditions	Provided all 4 conditions
Described how it met the model (relating to the DCI)	No descriptions	Only partially described how the model related to the conditions	Described how the model related to all 4 conditions
Provided evidence that natural selection occurred (using the Practice)	No evidence provided	Evidence was provided, but did not relate to natural selection	Evidence was correctly provided

Name of PE	Performance Expectation (PE)			
HS-LS4-3.	Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.			
Fitness Assessment				
<i>Fitness is a term often used by biologists to explain the evolutionary success of certain organisms. Below are descriptions of four fictional female lizards. Which lizard might a biologist consider to be the “most fit?” Explain why the lizard is most fit using evidence from the data table.</i>				
	Lizard A	Lizard B	Lizard C	Lizard D
Body Length	20 cm	12 cm	10 cm	15 cm
Offspring surviving to adulthood	19	28	22	26
Age at death	4 years	5 years	4 years	6 years
Comments	Lizard A is very healthy, strong, and clever	Lizard B has mated with many lizards	Lizard C is dark colored and very quick	Lizard D has the largest territory of all the lizards
Rubric				
Dimensions being assessed	0	1	2	
Correctly identified lizard B as being most fit (relating to the DCI)	No answer	Identified an incorrect lizard	Identified lizard B	
Used evidence to explain choice (using the Practice)	No evidence given	Provided incorrect evidence	Correctly stated that lizard B mated with many lizards and/or had the most offspring surviving to adulthood	

Name of PE	Performance Expectation (PE)		
HS-LS4-4.	Construct an explanation based on evidence for how natural selection leads to adaptation of populations.		
<b>Natural Selection and Genes Assessment</b>			
<p><i>[Assessment questions was the final question on a lab that modeled natural selection within a population]</i></p> <p><i>Write a statement that summarizes how the genetic makeup of a population changes with changes in the environment.</i></p>			
<b>Rubric</b>			
Dimensions being assessed	0	1	2
Related changes in the environment to changes in the populations due to genetic variation (relating to the DCI)	Not answered	Attempted but incorrect	Related changes in the environment to changes in the populations due to genetic variation
Constructed an explanation using scientific reasoning (using the Practice)	Not answered	Explanation attempted, but lacking details	Constructed an explanation using scientific reasoning

APPENDIX D

PRE AND POST NGSS STUDENT CONFIDENCE SURVEY

Thank you for participating in my survey. The information gathered here will be very valuable in my graduate school research. Participation in this research is voluntary and participation or non-participation will not affect your grade in any way.

1. Name: \_\_\_\_\_

2. Regarding the Science Practices, how confident are you at...

	<b>Very confident:</b> I could teach this to someone else	<b>Confident:</b> I am pretty sure I would get this correct	<b>Somewhat confident:</b> I would be unsure if my answer was correct	<b>Not confident:</b> I wouldn't know where to begin
<b>asking questions</b> to determine relationships between independent and dependent variables?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>using and/or constructing models</b> to predict, explain, and/or collect data?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>planning and carrying out investigations</b> individually and collaboratively?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
using tools and technologies to <b>generate and analyze data</b> in order to make scientific claims?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>using mathematical thinking</b> to identifying patterns in large data sets?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>constructing explanations</b> for relationships between variables?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
comparing two <b>arguments from evidence</b> in order to identify which is better by identifying flaws in logic or methods?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>obtaining, evaluating, and communicating information</b> using scientific language and reasoning?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**3. Select the Cross Cutting Concept that BEST fits the science concept.**

	Patterns	Cause & Effect	Scale, Proportion, & Quantity	Systems & System Models	Energy & Matter	Structure & Function	Stability & Change
The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugar plus released oxygen.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The structure of DNA determines the structure of proteins. The structure of proteins determines its role in living things.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
There are different variations and distributions of traits within a species.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Feedback mechanisms maintain a living system's internal conditions, allowing it to remain alive and function even as external conditions change. This process is called homeostasis.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Closely related organisms show similarities in DNA sequences, anatomical structures, and order of appearance of structures in embryological development.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
The traits that positively affect the survival of an organism are more likely to be reproduced, and thus are more common in the population.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Multicellular organisms are organized in a way that cells make up tissues, tissues make up organs, organs make up organ systems and organ systems make up the organism.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

\*Administered using the website [www.surkeymonkey.com](http://www.surkeymonkey.com)

APPENDIX E

PRE AND POST NGSS TEACHER CONFIDENCE SURVEY

**X** Pre-Treatment Survey

**X** Post-Treatment Survey

**1. Regarding the Science and Engineering Practices, how confident are you at teaching the concepts associated with...**

	<b>Very confident:</b> I feel I can and already teach this	<b>Confident:</b> I could easily modify my methods to teach this	<b>Somewhat confident:</b> I would need extra time to prepare for lessons associated with this	<b>Not confident:</b> I would avoid this because it's not my comfort area
<b>asking questions</b> to determine relationships between independent and dependent variables?	<b>X</b>	<b>X</b>	<input type="radio"/>	<input type="radio"/>
<b>using and/or constructing models</b> to predict, explain, and/or collect data?	<input type="radio"/>	<input type="radio"/>	<b>X</b>	<b>X</b>
<b>planning and carrying out investigations</b> individually and collaboratively?	<input type="radio"/>	<input type="radio"/>	<b>X X</b>	<input type="radio"/>
using tools and technologies to <b>generate and analyze data</b> in order to make scientific claims?	<input type="radio"/>	<b>X</b>	<input type="radio"/>	<b>X</b>
<b>using mathematical thinking</b> to identifying patterns in large data sets?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<b>X X</b>
<b>constructing explanations</b> for relationships between variables?	<input type="radio"/>	<input type="radio"/>	<b>X X</b>	<input type="radio"/>
comparing two <b>arguments from evidence</b> in order to identify which is better by identifying flaws in logic or methods?	<input type="radio"/>	<input type="radio"/>	<b>X</b>	<b>X</b>
<b>obtaining, evaluating, and communicating information</b> using scientific language and reasoning?	<input type="radio"/>	<input type="radio"/>	<b>X X</b>	<input type="radio"/>

**2. How confident are you in your ability to incorporate and communicate the following Cross Cutting Concepts into your biology lessons?**

	<b>Very confident:</b> I feel this is something I already do or can do very easily	<b>Confident:</b> I feel these concepts can be taught with only a little adjustment	<b>Somewhat confident:</b> I would need extra time to prepare for lessons associated with this concepts	<b>Not confident:</b> I would have a difficult time incorporating this concept into my lesson
Patterns	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Cause & Effect	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scale, Proportion, & Quantity	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Systems & System Models	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Energy & Matter	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Structure & Function	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Stability & Change	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>

APPENDIX F  
INTERVIEW QUESTIONS

*Not all questions will be used with each assessment, that will depend on the assessment and the lesson itself.*

**Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.**

1. How did you feel about the assessment you just took?
  - a. Why was it easy? OR Why was it hard?
  - b. How does it compare to other assessments you take (in this class or others)?
2. Can you use this assessment/lesson and apply it to your daily life?
  - a. When might you use this skill in the future?
3. How do you feel about identifying the practices of science?
  - a. Do you think it's important to learn about the practices?
  - b. Why?
4. How do you feel about identifying the cross-cutting concepts?
  - a. What are some other areas of your life (or other school topics) that relate to this cross-cutting concept?
5. Do you enjoy learning this way?
  - a. Why or why not?
6. Why did your confidence go up in the area of \_\_\_\_\_?
7. Why did your confidence go down in the area of \_\_\_\_\_?

\* When students are not very open ended in their responses – follow up with “Tell me more.”