THE USE OF INQUIRY-BASED INSTRUCTION TO INCREASE MOTIVATION AND ACADEMIC SUCCESS IN A HIGH SCHOOL BIOLOGY CLASSROOM

by

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July 2011

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For Tony, who makes all things possible and encourages me each day to never stop exploring, learning, and loving our world.

TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND 1

CONCEPTUAL FRAMEWORK 4

METHODOLOGY 8

DATA AND ANALYSIS 14

INTERPRETATION AND CONCLUSION 27

VALUE 31

REFERENCES CITED 34

APPENDICES 36

APPENDIX A: The Matrix for Assessing and Planning Scientific Inquiry 37
APPENDIX B: The Student Science Survey…………………………………......40
APPENDIX C: Student Science Inquiry Survey……………………………… .42
APPENDIX D: What Helped Me Learn Genetics………………………………45
APPENDIX E: Science Skills Assessment 47
APPENDIX F: Exemption Form Regarding Consent 49

LIST OF TABLES

1. Triangulation Matrix 13

2. Total Averages of Student Results per District Testing Over a Four Month Time Period 19

3. Averaged Data Results of the Pre, Mid, and Post Student Science Inquiry Survey 23

LIST OF FIGURES

1. Percentage of Student Response to the Question: *Are you excited and motivated to come to science class* 14

2. Percentage of Student Response to the Question: *How Do You Feel About Your Abilities to Do Science* 15

3. Percentage of Student Response to the Question: *What Kinds of Activities Do You Enjoy in Science Class* 15

4. Percentage of Student Response to the Questions: Do You Feel You Have Enough Help in Science Class; Do You Receive Enough Feedback on Assignments, Projects, and Labs from the Adults in Your Life; Do You Feel You Should Be Rewarded with Things for Completing Science Work to the Best of Your Abilities 16

5. Percentage of Student Ranking per Inquiry and Non Inquiry based Strategies: *What Helped Me Learn Genetics* 17

6. Percentage of Students were ranked *high, average, low* per scientific inquiry standard on MAP test 18

7. Percentages per letter grade for the End of Course for Biology Exam Scores 20

8. Percentage of Students were ranked *best, adequate, not met* per category on the Student Skill Assessment for *TD = teacher driven lab* and *SD = student driven lab investigation* 21

9. Percentage of Student responses, *highly confident*, *somewhat confident*, and *not confident*, per science skill category for each pre, mid, and post student science self assessments 24

10. Percentage of Student responses, *highly confident*, *somewhat confident*, and *not confident*, per science skill category for each pre, mid, and post student science self assessments. 25

11. Percentage of Student responses, *highly confident*, *somewhat confident*, and *not confident*, per science skill category for each pre, mid, and post student science self assessments 26

ABSTRACT

A variety of inquiry based lessons and non inquiry based lessons were used to motivate and increase academic success with a freshman biology honors students. Student self surveys, biology journals, and lab skills were indicators of motivation. Scores on standardized tests and other assessments were used to monitor students' academic success. Trends indicated an increase in student motivation to do science while testing scores were varied.

INTRODUCTION AND BACKGROUND

Project Background

Teaching Experience and Classroom Environment

Five years ago, I switched career fields from a research coordinator with a university ecology laboratory to a high school biology teacher. Initially, I was able to work part-time with the lab while teaching full time. This opportunity allowed me the unique ability to develop scientific inquiry with my students. We worked together on real world environmental problems with many professional scientists in the community. Throughout the school year, the students were excited and motivated in part due to the many labs and activities related to their studies. They were able to experience “real” applications of their efforts and the significance of scientific inquiry based skills. At the end of the school year, reduced funding caused the near closure of the lab, and my part time employment ended. I decided to move closer to my family and relocated to Beaufort, South Carolina. I was hired at Beaufort High School and taught biology for two years. Based on my first year of teaching, I wanted to apply scientific inquiry based investigations with my new students. As I continued to teach with this method in mind, I observed a slight increase in student achievement associated with scientific inquiry based activities and labs conducted outdoors. During my second year at the high school, I was contacted by the principal of Whale Branch Middle School and asked if I would consider becoming part of their newly developed fifth grade STEM (science, technology, engineering, and math) academy. I was excited to be part of new national pilot program centered on science, so I took the appointment. While at Whale Branch Middle School, I continued to develop a science curriculum centered in inquiry based learning. I expanded the laboratory investigations to include as much environmental education as possible and we worked to incorporate improving the natural landscape as much as possible. Over the course of that school year, I observed an increase in student motivation and confidence levels to "do" science – students were excited to come to school, check on classroom projects, and go outside to apply science skills. The next school year I was assigned a new school. H. E. McCracken School is located in the southeastern island/ marshlands of Beaufort County, South Carolina. It is the last town before Hilton Head Island. During the early turn of the century, this coastal area was booming with new development. This once vast area of marshlands quickly became a popular tourist destination for outlet shopping, dining, and golf. However, in recent years this coastal community has suffered due to national economic hardships. Development suddenly ended, tourism dropped, and people were left to seek other sources of income. There are large families in this area and many had relocated due to the fast rising jobs and easier climate. Despite the economic down-turn, many of these families have remained in the area. The small and few local schools serve over 17, 500 people in this town (schooltree.org). The local high school was overcrowded due to the prediction many people would leave the area for employment. To address the overcrowding issued, a new middle school was built in the summer of 2010. H. E. McCracken School was the former middle school but now serves as a junior high school for 8th and 9th grade only for the community. The majority of the school population is Caucasian and approximately 34% of the students receive free or reduced lunch services (schooltree.org). I serve 82 students at the school and teach Biology I, Honors to 9th graders.

Students need time and experience to develop the skills of learning how to observe and monitor change. Students need to know how to interpret scientific data and evaluate the meaning of the data. Students should have the abilities to communicate this information in order to make the right choices. Since my goal was to determine if scientific inquiry based labs increase student motivation and academic success, various investigations and activities were implemented from January through April. Some investigations were more inquiry based than others, but all had the goals of helping student develop scientific skills and become more science literate. This research project was centered on the development of a curriculum immersed in inquiry based activities and laboratory investigations conducted in indoor and outdoor settings. Student motivation, academic performance, and development of inquiry skills were monitored and measured.

Focus Question

Underlying my primary focus question were some additional questions. What were my students' views of science, their abilities to do science, and how science literate were they? I wanted to determine if an increase in the complexity of inquiry based learning would benefit student academic success in the biology classroom. I researched each of these to help support my project findings related to their existing thoughts, beliefs, and feelings about science. I wanted to understand my ninth grade biology students and their experiences with regards to science and determine potential growth in science literacy and science skills during the course of the project. It was also important to determine if confidence in their abilities to "do" science influenced their academic success.

CONCEPTUAL FRAMEWORK

Scientific inquiry based learning is known by several different names: discovery based learning, problem based learning, hands-on science, mind-on science, investigative learning, real world problem solution, and experimental design process. Despite all the names, there is little variation in the pedagogical implementations and theory among the titles (Brooks & Brooks, 1993; Bruner, 1961; Dewey, 1910). Simply stated, an inquiry based classroom is an environment in which students are actively engaged and progressing towards becoming literate about what science is, what science looks like, how to do science, and how to communicate science (NAP, 1996; AAAS, 1993). There is significant purpose in inquiry based classroom and instruction. In an inquiry based learning classroom, learners model scientists. All scientific pursuits are led by a question or series of questions designated at determining the, whys or what ifs of a natural phenomenon. In an inquiry based learning environment, it is obvious and evident the teacher allows the students to ask questions and pursue investigations (Yager, 2009; Llewwllyn, 2005). Students need to have the tools and ability to develop authentic questions for inquiry purposes (Windschitl, 2001). Inquiry based classroom teachers make all necessary tools and materials available and welcome students to explore their own questions relevant to science and topics studied during our school year. In the classroom, the teacher displays student extended investigations, various mapping techniques of students' conceptual understanding of science topics, and other forms of student work are readily available; such as, notebooks, journals and portfolios. Those student artifacts are evidence the learners and instructor are actively doing inquiry based science. Teachers who encourage a holistic atmosphere and approach to inquire based learning instruction, are led by the state and nation science standards and the 5-E Learning Cycle: engage, explore, explain, extend, evaluate (Llewwllyn, 2005). Preferable, students develop inquiry skills at a young age. These skills are enhanced in the classroom throughout a student's academic career (NAP, 1996; AAAS, 1993). The earlier these skills are developed, the more analytical and aware a child becomes about local and global issues.

Studies dismiss the role of unguided scientific inquiry in the science classroom as a means to increase student academic success (Kirschner et al., 2000; Berkson,1993). According to these studies, students need direct instruction from an educator in order to best understand concepts and procedures. Researchers suggest that guided instruction increases student cognitive abilities, and therefore information is retained in long term memory (Kirschner et al., 2000). This is in some opposition to earlier theorists' proposals that students should be left to explore and construct information on their own with very minimal assistance from an educator (Bruner, 1961; Dewey,1910). Current literature on pedagogical implementation and design of scientific inquiry in the classroom suggest a slightly different role for the educator than historically presented (Marx et al., 2004; Crawford, 2000; Tam, 2000; Holbrook & Kolodner, 2000). In a scientific inquiry based classroom environment, traditionally the role of the educator was to only facilitate, leaving the students to actively explore and engage in scientific problem solving activities. The facilitator role is still present, but educators must also academically challenge students with new questions for exploration, allowing students to build or scaffold higher level questioning in addition to exercising problem solving techniques. When new information is manipulated in a guided manner by educator and student, it is then contextually stored in long term memory (Kirshner et al., 2006; Pillay, 1994). Educators in a modern scientific inquiry based classroom are, most importantly, collaborators with students in doing, learning, and communicating science (Crawford, 2000; Tam, 2000, Krajcik et al., 1994; NAP, 1996).

Educators who collaborate with students in guided scientific inquiry based lessons and activities increase student motivation (Crawford, 2000; MacIver et al., 2001; Marx et al., 2004; Holbrook & Kolodner, 2000). The need for students to feel cared for and invested in is highly important. A person willing to work with a student can reduce stress induced from physical, social, and mental transitions (MacIver et al., 2001). Opportunities for open collaboration and group work are also essential to students in the inquiry based science classroom (Llewwllyn, 2005). Group work and group presentations can help alleviate the side effects of peer pressures and motivate the otherwise introverted student. Individual performance based tasks can often lead to embarrassment, fear, and dread (MacIver et al., 2001) decreasing student motivation and success. It is up to the educator to create an atmosphere in which students are comfortable and heard. Based on research findings of middle school science classrooms, motivation is directly related to the student awareness of his/her teacher's best efforts and deep concern for students' academic success (Wentzel, 1997; Wentzel, 1998).

Students are also academically motivated when they are collaborators with their educators in real world based problem inquiry studies (Hubbard, 2003; Bouillion & Gomez, 2001; Crawford, 2000; MacIver et al., 2001; Krajcik et al., 1994). Inquiry projects based on real world problems increases student science literacy, knowledge and abilities to confidently apply scientific methods (Krajcik et al., 1998). Instructional practices in the science classroom should include students hypothesizing and investigating real problems (MacIver et al., 2001). Students should be actively engaged in reading scientific literature, referring to guides and texts, and writing about science as they search for solutions to real world problems (Crawford, 2000; Krajcik et al., 1998; MacIver et al., 2001). During real world inquiry based investigations, educators should model scientists and guide students in accurate data collection (Crawford, 2000). Not only are the educators collaborators with their students during inquiry investigations, educators also collaborating with university professors, community partners, and other students (Crawford, 2000; Tam, 2000, Krajcik et al., 1994; NAP, 1996). Collaboration among researchers adds to the relevance of the investigations, thereby instilling excitement in students as scientists. Collaboration among community partners, concerned parents and citizens aides in bridging gaps between the community and the school. Bridging the gap is an effective tool in increasing community involvement and helping students feel connected to and an important part of their world (Bouillion & Gomez, 2001). If students feel more significant in the community with attention given on their studies, academic success and motivation will increase at the school and in the science classroom (Bouillion & Gomez, 2001; Crawford, 2000).

Nature or environmental inquiry projects aide in student awareness of community and global issues. As students turn into voters, it is essential they understand the democratic process and are scientifically literate. Students will vote on issues that will impact local and global environments and economies (NAP, 1996). It is imperative that science classrooms provide and foster the means for students to explore the natural world in order to develop a strong sense of place in the world. Real problem based scientific inquiry provides an opportunity for the educator and students to immerse themselves in a collaborative investigation based in the environment (Windschilt, 2001; Crawford, 2000). Environmental studies provide a robust method for student generated hypotheses and investigations of authentic questions leading to authentic solutions. Students who participate with guidance from an educator grow to understand the significance of their education and relevance of their potential impact on the world (Krajcik et al., 1998; Marx et al., 2004; Crawford, 2000). Students engaged in scientific inquiry based learning direct their own development of scientific skills. Students who take ownership in their own education will increase their drive to become more science literate and academically successful. In order to reach these goals, it is important to find a way to engage students whether it is the use of the natural landscape or any other exciting vehicle that helps maintain their interests in the many fields of science.

METHODOLOGY

For each major unit of study, I designed and planned a curriculum based on my expected outcomes regarding student understandings and skills by the end of each unit of study. The final assessments along with laboratory experiences and activities were determined prior to introduction of each unit of study to my biology students. A few additional labs and activities were incorporated into the units as I discovered new ideas that related to our topic of study. The units were separated into six categories, scientific inquiry, energy, genetics, evolution, and ecology, based on South Carolina State Science Standards. Scientific Inquiry was taught all year long while the other five units each extended over a one to two month time period. This research extended over the genetics unit of study. Mr. Shaw, school principal, signed my exemption for consent and approved my research project.

Since the goal of this project was to determine if scientific inquiry based instruction increased student motivation and academic success, I chose the Matrix for Assessing and Planning Scientific Inquiry (MAPSI) to authenticate our investigations (Appendix A). The MAPSI also provided me with a rank in the level of complexity of the lab investigations and activities. Inquiry based lessons and activities were implemented in all units of study. These included use of discrepant events, misconception probes, and various laboratory investigations. My research time extended over three units of study but I have selected one to present, genetics, because it is the most complete in terms of data. For activities and laboratory activities used to enhance the genetics unit of study and increase student science inquiry skills, the MAPSI chart was used to determine if the investigations were more or less student driven, and also used as a means to measure and validate the level of complexity of each of the investigations. I wanted to monitor if implementation of inquiry based lessons would be more or less challenging for students. If more challenging, this may result in a decrease of completion of student work, in this case a written lab report.

The MAPSI rank allowed me to compare results with other data instruments to observe any potential patterns. For each lab investigation and for a few activities I planned for lessons to along with the units of study, the MAPSI was used (1) to determine if the investigations were more or less student driven, and (2) as a means to measure and validate the level of complexity of each of the investigations and activities. Investigations were then categorized as either more *student driven* and inquiry based or categorized as *teacher driven* not inquiry based instruction. The MAPSI was used, like a rubric, to tally points for each step of the scientific method process. A rank of “1” was given to any category that was mostly teacher driven, a rank of “2” for steps that were moderately teacher driven, and a rank of “3” for steps that were student driven. Numbers were tallied per step and indicated a total rank for the investigation.

Students’ prior science knowledge, feelings, beliefs, attitudes, academic success, and science literacy were measured using the Student Science Survey (Appendix B). The Student Science Survey asked students to rank their knowledge and feelings about science. This survey was used to determine a range of student science literacy and general interest in science. The survey also helped determine if inside, outside, or a combination of both inside and outside science inquiry labs and studies proved most favorable to students to help plan labs and activities. Students’ scores were compared with other collected data for any potential pattern of students’ feelings about science and confidence levels to do science.

To determine if student motivation increased due to the application of scientific inquiry based investigations, students conducted several short term and extended biology related investigations. The investigations were geared towards increasing student science literacy skills. During this time, teacher observations of student performances were recorded to monitor student progress with laboratory science skills. Each week, students were requested to write a brief summary in their biology journal of the past week’s events in biology class. Student Biology Journals were read and monitored over time. Other student artifacts (class work, lab work, homework) were reviewed for completion and effort. Students were requested to write a brief summary each week in their laboratory journal All instruments were used as a measure of student academic progress and student motivation. To determine an increase in students' confidence in scientific inquiry over time, the Student Science Inquiry Survey was given out three times (beginning, midterm, and end) during the course of this research project. Students' scores from each administration were compared to determine any changes in response to the survey questions. To initiate my research project and data collection, students were given the Student Science Inquiry Survey (Appendix C). The survey consisted of 39 statements which were separated into nine categories. The categories were identified as a specific stage of the scientific inquiry process. Each student was asked to rate their own confidence level (very confident, confident, not confident) per each statement based on their current abilities to perform the specified task. The survey was given to all of my biology honors students to determine how confident my students were at doing science. The same survey was given two more times during the course of my research. The data was analyzed to determine patterns in growth in confidence levels with performing scientific inquiry. Student survey responses for each statement were converted by using a Likert-scale: 1 = I am very confident on my abilities, 2 = I am somewhat confident in my abilities and 3 = I am not confident in my abilities. The data were compiled into a spreadsheet for analysis purposes. Once all the responses were entered into the spreadsheet per student, the 39 statements were categorized into nine stages of inquiry. These stages included, exploring, questioning, identifying a statement to test, designing a procedure for an investigation, using the investigative plan, collecting data for evidence, communicating results of an investigation, researching for scientific knowledge related to investigation, and extending investigations.

Students were also asked to complete the What Helped Me Learn Genetics Survey which asked students about their study habits and also likes and dislikes about biology class (Appendix D). Students' scores were used to determine if a relationship of confidence in science inquiry skills related to how students felt about the materials presented in biology classroom.

For comparison purposes with inquiry-based investigations, several traditional laboratory investigations were conducted during each unit of study. Data from Teacher Student Science Skills Assessments and other student artifacts such as Student Biology Journals were used for comparison purposes (Appendix E). Two laboratory investigations were chosen for comparisons, one student driven and the other teacher driven as ranked by the MAPSI analysis.

Measure of Academic Progress (MAP) tests were given to students in the winter of 2010 for biology. The questions are labeled according to the particular content or science standard they represent. I selected questions related to scientific inquiry and used scores to measure academic growth in this area. Students are ranked high, average, or low per measured science standard based on percent of correct answers. For this research, two standards were used, Hypothesis/Questions/Design and Design/Scientific Investigations. Other measures of academic progress included, a common district-wide approved biology mid-term test issued to students in January, another district-wide benchmark test given in mid April of 2011, and the South Carolina End of Course Exam for Biology (EOC) given the first week of June. Students were also assigned computer-based quizzes with a random mixture of scientific inquiry and content study questions based on specific state science standard indicators. The computer-based quizzes are issued though our district as a tool used for helping students prepare for the end of year tests and finals. Scores from the mid-term test, benchmark test, computer quizzes, along with all unit test scores were used as measures of student academic progress. Scores were used to identify patterns of growth and correlated with survey data and other collected data. The data sources provided a triangulation matrix combined with my focus question and the other sub questions regarding the use of scientific inquiry to increase student motivation and academic success (Table 1).

Table 1
Data Triangulation Matrix

Research Questions	Data Sources 1	Data Sources 2	Data Sources 3
1) What are my students' existing knowledge of and feelings, beliefs, attitudes toward science and academic success?	Student Science Survey	Student Science Inquiry Survey	Teacher Observations Log
2) How scientifically literate are my students at any given point (can they "do science" that we learn in the classroom)?	Student Biology Journals	Comparisons of MAP Scientific Inquiry scores	Student Artifacts (completion of homework, classroom, effort in labs and activities)
3) Will the use and complexity of inquiry-based labs and activities increase student science skills and motivation?	Student Science Inquiry Survey	Student Biology Journals	Teacher Student Science Skills Assessments; MAPSI
4) Will increase motivation result in an increase in academic success?	Comparisons of MAP scores, Midterm, Benchmark, computer based tests	Comparisons of Units of Study assessment scores	Teacher Observation Log Student Biology Journal

DATA AND ANALYSIS

Measures of students' motivation to come to science class were measured in late fall of the school year with the Student Science Survey (Appendix B). Survey results revealed about half of the students, 53%, were excited and motivated to come to a science class (*N*=68). The other half of the students indicated they were split between *maybe*, 22%, and *not*, 25%, excited and motivated to come to class (Figure 1).

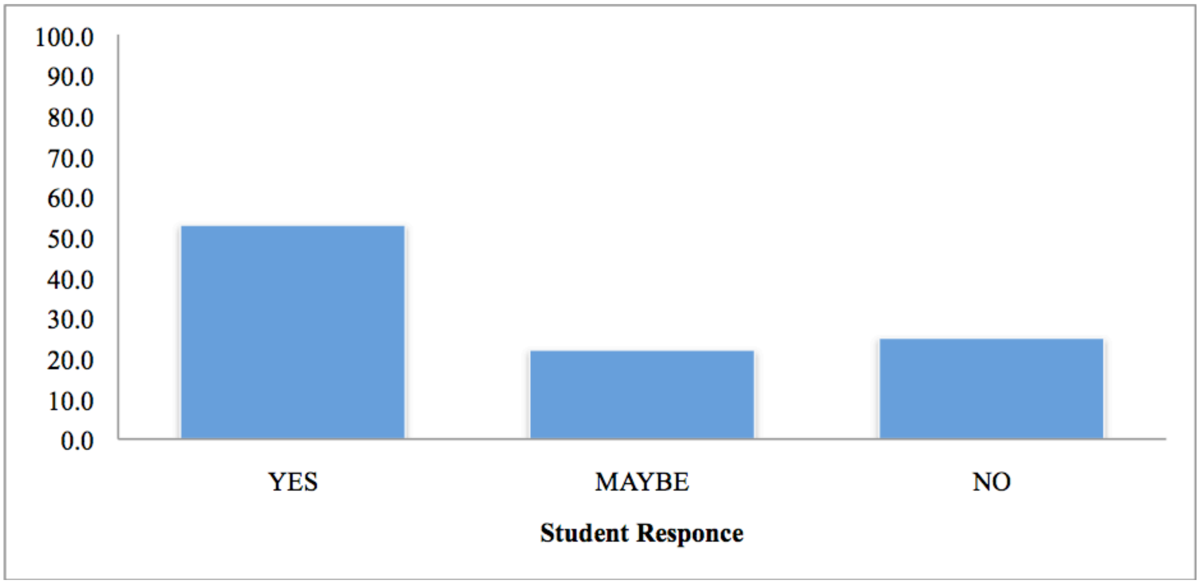

Figure 1. Percentage of Student Response to the Question: *Are you excited and motivated to come to science class*, (*N*=68).

Similar patterns are observed in student responses to their own abilities to do science in the science classroom. The majority of students surveyed feel *confident* in their abilities, 52%, (*N*=68). Other students indicated they were *somewhat confident*, 38%, or *not confident*, 10%, in their abilities (Figure 2).

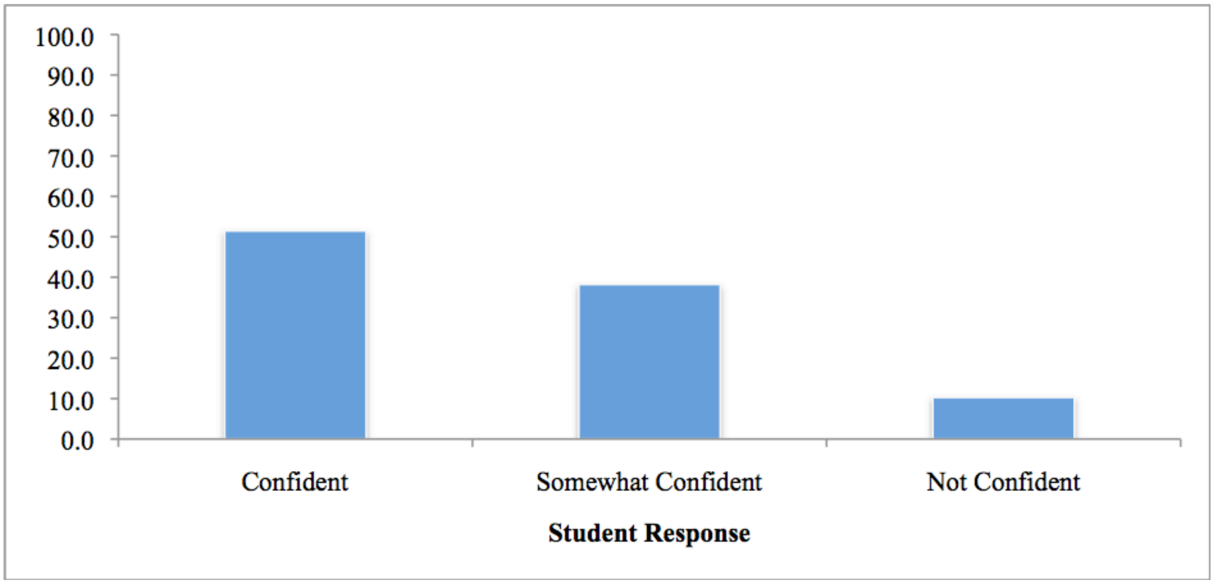

Figure 2. Percentage of Student Response to the Question: *How Do You Feel About Your Abilities to Do Science*, (*N*=68).

Student Science Survey results indicate the majority of students, 82%, enjoy *laboratory* investigations in science class. Other activities were written on the survey, such as *creative assignments*, 9%, any kind of group work, 4%, and even *games* and *worksheets*, each 1%, while one student indicated *nothing* (Figure 3).

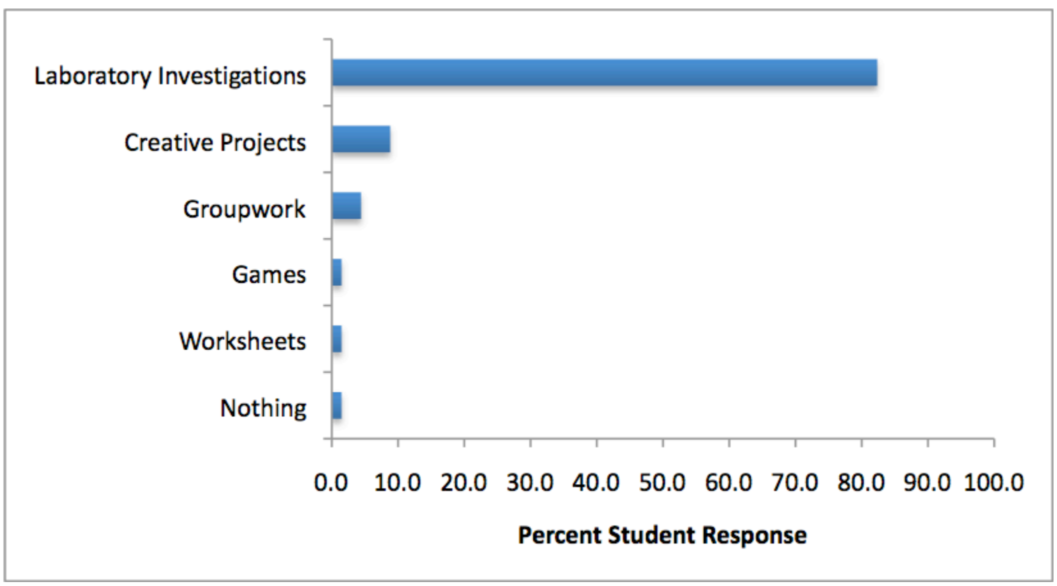

Figure 3. Percentage of Student Response to the Question: *What Kinds of Activities Do You Enjoy in Science Class*, (*N*=68).

Measurements of what motivates students to do science and complete science indicate, most students feel they *receive ample support* with their science work, 84%, and *adult feedback*, 85%. Student responses were almost equal towards feeling they should be *rewarded for completing science work*, 44%, and *not rewarded*, 46%, for completion purposes. While other had somewhat mixed feelings about a reward system, 10%, (Figure 4).

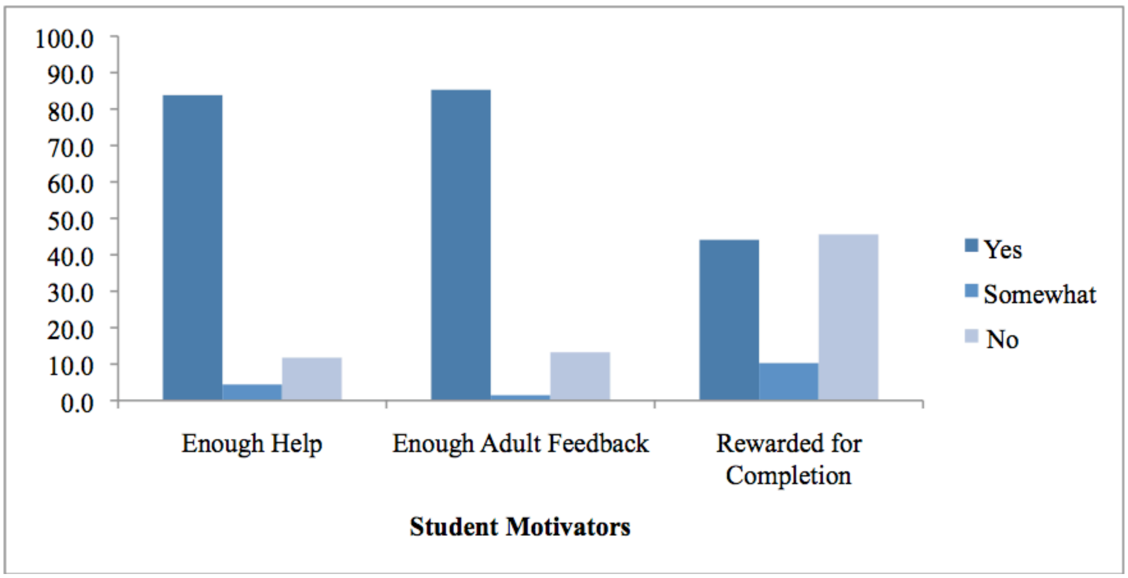

Figure 4. Percentage of Student Response to the Questions: *Do You Feel You Have Enough Help in Science Class; Do You Receive Enough Feedback on Assignments, Projects, and Labs from the Adults in Your Life; Do You Feel You Should Be Rewarded with Things for Completing Science Work to the Best of Your Abilities*, (*N*=68).

Later in the school year, students were asked to write responses to two questions regarding motivation and their studies in biology class. The first question was, *thinking about this past school year in biology class, please list anything that motivated you to come to class or got you excited to learn about and do science.* Students were also asked to include items that were not motivators. The majority of student responses indicated they were motivated by the variety of activities, labs, and a few specifically mentioned a topic we studied. Many students indicated mini-lectures and note taking were least motivating items but they learned a great deal. The second question students were asked to respond to, *what motivated you to do well in biology or try your hardest.* The overwhelming majority responded parents and the need to do well for college.

Additionally, students were asked to complete a What Helped Me Learn Genetics survey. Data result indicated student found laboratory investigations most effective in terms of effective tools for learning and motivating (Figure 5). Inquiry based, student driven labs were determined slightly more effective over the teacher driven labs.

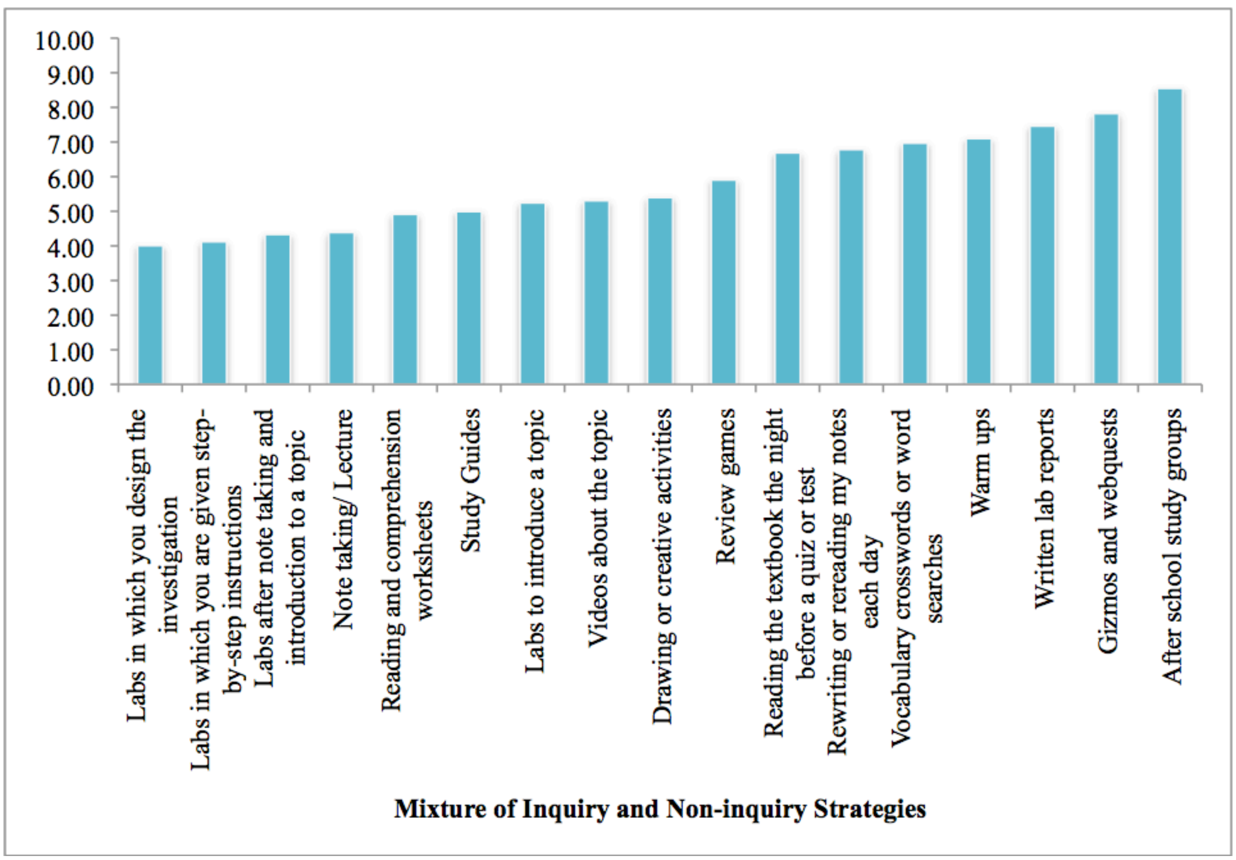

Figure 5. Results of What Helped Me Learn Genetics student ranking of 14 inquiry and non inquiry based strategies used in class to study genetics. Students ranked the strategies numerically *1* to *14*, lower percentages represented strategies students found most effective, (*N*=80).

To determine if increased motivation resulted in increased academic success, various assessment scores were used for comparison purposes. Biology MAP test results indicated the majority of students, 83% and 80%, were ranked *high* in both scientific inquiry standards (*N*=80). Few students were ranked *average*, 11% and 19%, per standard and even less were ranked *low*, 6% and 1% (Figure 6).

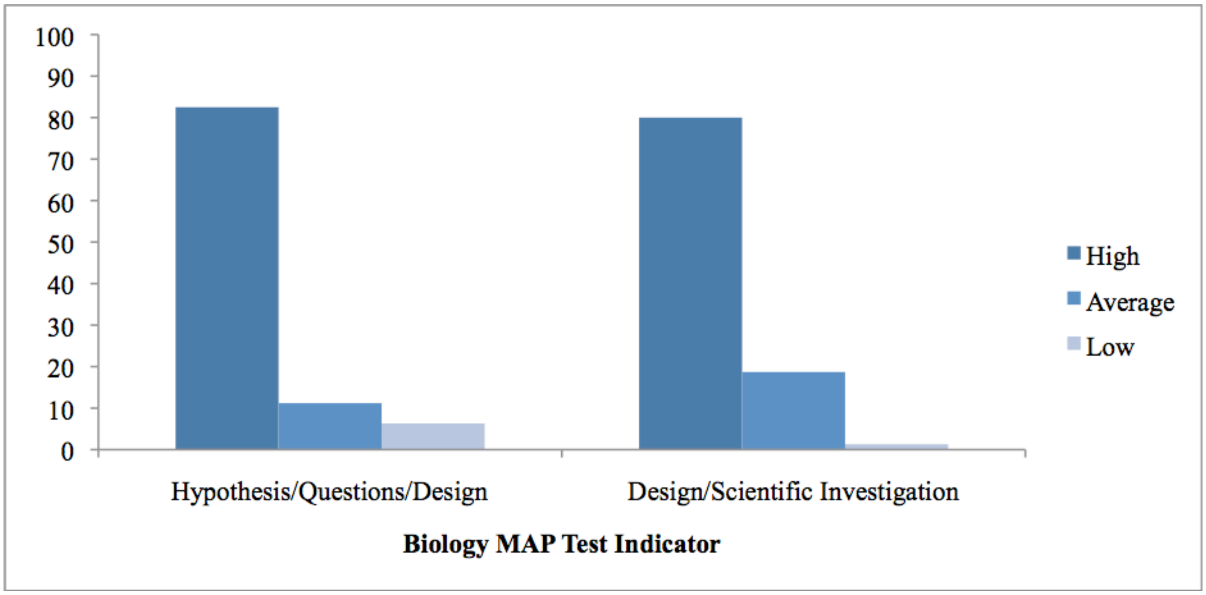

Figure 6. Percentage of Students were ranked *high, average, low* per scientific inquiry standard on MAP test, (*N*=80).

The school district biology January midterm, combined computer based quizzes, and biology April benchmark averaged results did not provide an obvious pattern of student academic success over a four month time period (*N*=80). Questions per indicator were randomized and not equally distributed over time (Table 2).

Table 2

Total percent averages of student results per district testing over a four month time period, (N=80).

Scientific Indicator *(# of questions per indicator)*	January Midterm *(2)*	Combined Computer-based Quizzes *(varied from 0 to 10)*	April Benchmark *(1)*
Appropriate Lab Procedure	41%	75-89%	58%
Compare Investigation Technical Design	81%	90%	28%
Design Scientific Investigation	75%	66-79%	80%
Evaluate Controlled Scientific Investigation	62%	n/a	95%
Evaluate Technological Design Product	87%	32-57%	27%
Generate Evidence-based Hypothesis	97%	65-94%	95%
Organize and Interpret Data	68%	56-94%	74%
Use of Appropriate Safety Procedures	84%	99%	72%
Use of Scientific Instruments	61%	48-59%	83%

The South Carolina End of Course for Biology Exam (EOC) scores indicated approximately 90% of my students scored an *A* or *B* letter grade. My students had the highest overall EOC scores in comparison with the students at McCracken that I did not teach and also with the rest of first year biology students in the entire district (Figure 7).

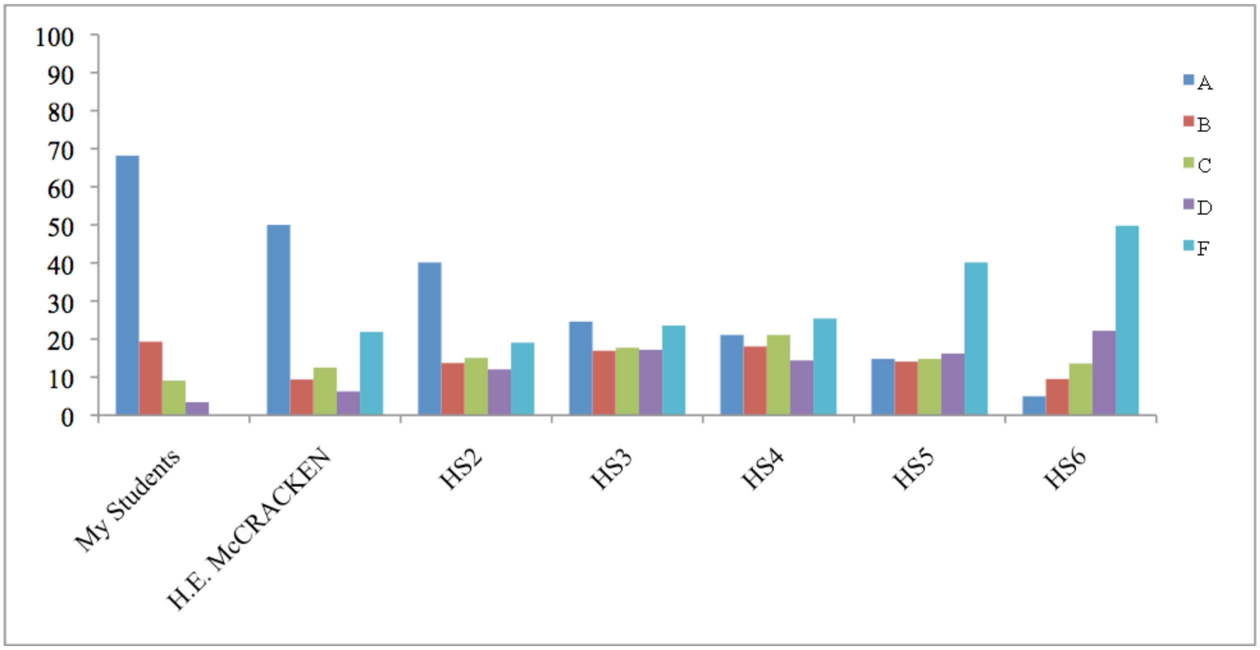

Figure 7. A comparison of Beaufort County biology students per high school percentages of students who scored an *A, B, C, D*, or *F* on the South Carolina End of Course for Biology Exam, (*N*=1459).

There were a total of 10 major activities and laboratory investigations. According to the results of the MAPSI ranking, six of these ten investigations were more teacher driven than student driven and thereby less complex. Four of the 10 were ranked more student driven and thus more complex by MAPSI. The MAPSI data results helped determine and categorize more inquiry based investigations from less inquiry based investigations for student surveys. Student data results of the Science Skills Assessment from two laboratory investigations, one ranked student driven and the other teacher driven by MAPSI, reveal a general trend that most students ranked *adequate* for each skill in both lab examples (*N*=71). However, comparisons of student results indicated *best* and *adequate* totals in students' abilities in generating *questions, prediction, and hypothesis* were lower with the student driven lab (85%) than those of the teacher driven lab (93%). The same was observed in the skill category, *interpretation of data and experiment.* Data results show a lower percentage of students scored in the *best* and *adequate* with student driven lab (65%) compared to teacher driven lab (89%) for the skill category, *interpretation of data and experiment* (Figure 8).

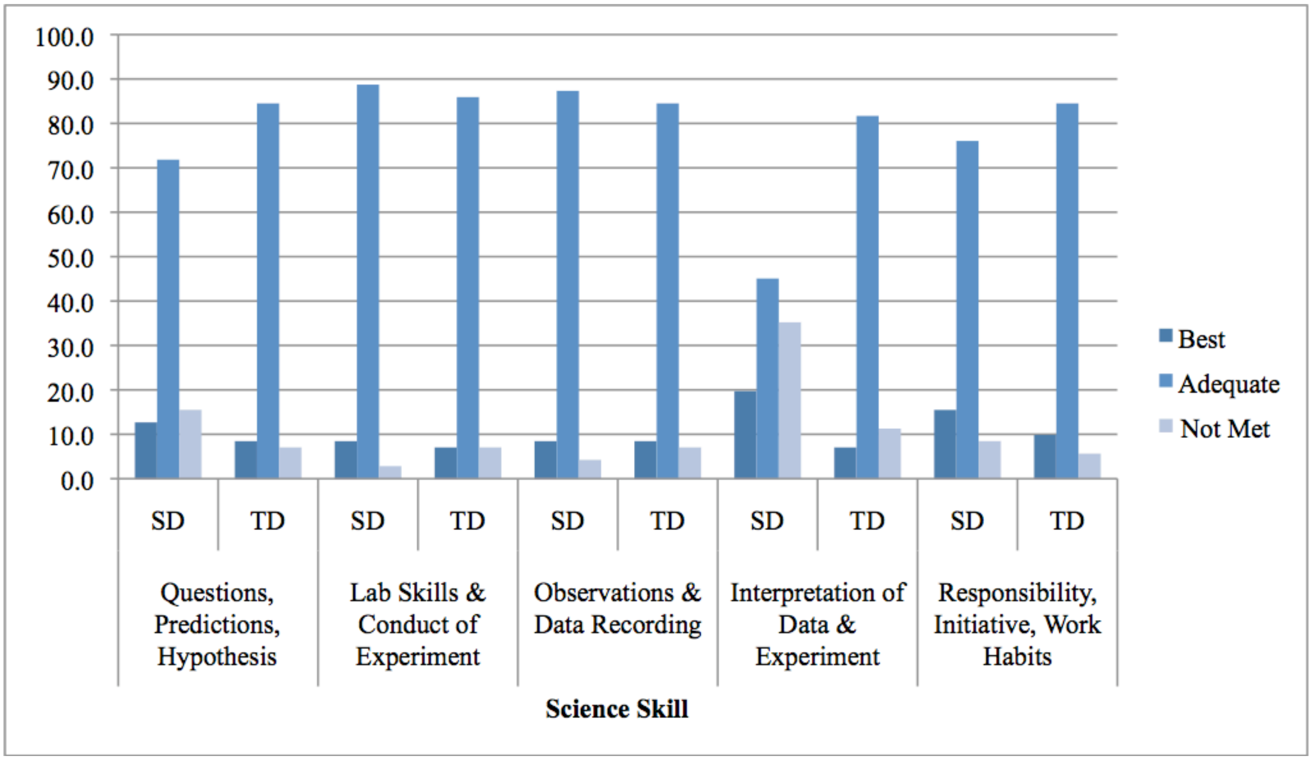

_*Figure 8.* Percentage of Students were ranked *best*, *adequate*, *not met* per category on the Student Skill Assessment for *TD = teacher driven lab* and *SD = student driven lab investigation*, (*N*=71).

Written laboratory report grades for the student driven and teacher driven investigations were used as additional assessments of *interpretation of data and experiment* skill category. The data averages indicated no notable differences in the actual percentages, respectively. However, there was a notable difference in terms of numbers of students motivated to complete the laboratory report assignment. The student driven laboratory report average was 63.4% and this percent included eight zeros due to incompleteness. The averaged grade was 65.3% for the teacher driven laboratory (*N*=81).

Although this percentage is slightly higher, 21 students did not complete the assignment (*N*=81). Because students were not motivated to complete the assignment, there were three times the number of zeros recorded in the grade book for that particular assessment.

The results of the weekly laboratory journal summaries indicate many students were highly motivated to come to class and enjoyed the variety of work, activities, and lab investigations. Many also indicated they were excited to see what would happen in the week to come. They expressed an appreciation for the variety of inquiry based lessons and include specific references to discrepant events, misconception probes, and inquiry based lab investigations. Note taking and lecture were not favorable activities and mentioned as such in student summaries.

Data sums of the Student Science Inquiry Survey were tabulated per category. The sums were grouped into the nine stages of inquiry skills. Percentages per stage of inquiry skill per *pre, mid, and post* were compared. Data was only used for students who completed each of the three surveys (*N*=62). Comparisons of pre, mid, and post survey data results indicated an increase in all skills over time ranging from 8.5 % to 22% in the *high confident* category (Table 3).

Table 3
Averaged data results of the Pre, Mid, and Post Student Science Inquiry Survey. Students assessed their own abilities in each skill as HC = highly confident, SC= somewhat confident, or NC = not confident (N=62).

	Pre	**Mid**	**Post**
Exploring			
HC	46.4	56.5	62.5
SC	45.2	39.1	31.0
NC	8.5	4.4	6.5
Questioning			
HC	44.1	46.2	57.0
SC	44.6	44.6	36.0
NC	11.3	9.1	7.0
Identifying a Statement to Test			
HC	46.8	58.1	66.9
SC	46.0	37.9	31.5
NC	7.3	4.0	1.6
Designing a Procedure for an Investigation			
HC	51.8	57.8	60.4
SC	34.8	35.7	31.3
NC	13.4	6.5	8.3
Using the Investigation Plan			
HC	73.1	77.4	83.1
SC	24.7	19.9	13.7
NC	2.2	2.7	3.2
Collecting Data for Evidence			
HC	61.5	65.3	70.2
SC	32.7	31.7	28.0
NC	5.8	3.0	1.8
Communicating Results of an Investigation			
HC	45.2	47.3	62.0
SC	40.9	46.8	31.2
NC	14.0	5.9	7.0
Researching for Scientific Knowledge Related to an Investigation			
HC	32.3	43.5	54.3
SC	58.1	45.2	35.5
NC	9.7	11.3	10.2

Extending Investigations			
HC	38.7	44.1	53.8
SC	48.9	44.1	37.6
NC	12.4	11.8	8.6

Of the nine stages measured, two stood out in pre and post data comparisons in the *highly confident* student assessment category. Those stages included *researching for scientific knowledge related to an investigation* (22% increased from pre to post survey) and *identifying statements to test* (20.2 % increased from pre to post survey). A closer look at these skills revealed an almost doubled increase from pre to post data comparisons with, *researching for scientific knowledge related to an investigation* in *highly confident* self rank (Figure 9).

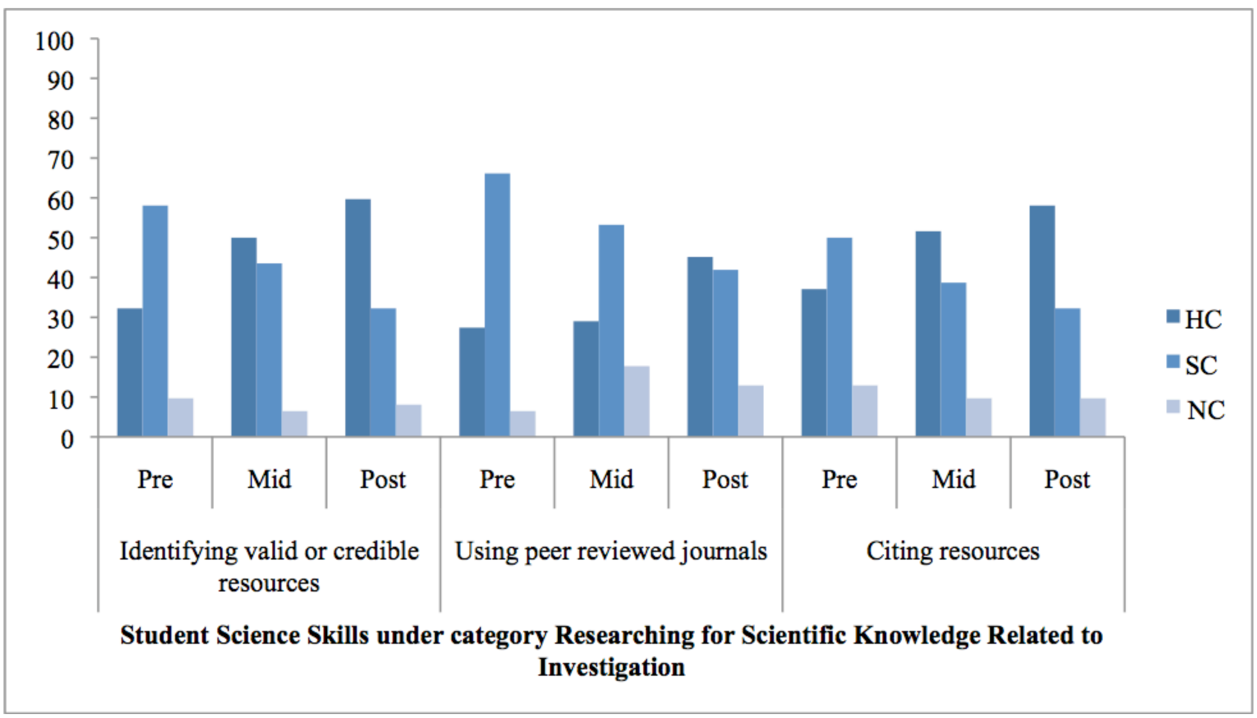

Figure 9. Percentage of Student responses per science skill category for each pre, mid, and post student science self assessments. (*N*=62). *Highly Confident (HC), Somewhat Confident (SC),* and *Not Confident (NC).*

There was not as much of an increase with skills included in the *identifying statements to test* data result comparison (Figure 10). The stage that received the least amount of difference between pre and post data results included, *designing a procedure for an investigation* (8% increased from pre to post survey). Students struggled with their abilities to identify variables such as independent and dependent variables in an experiment (Figure 11).

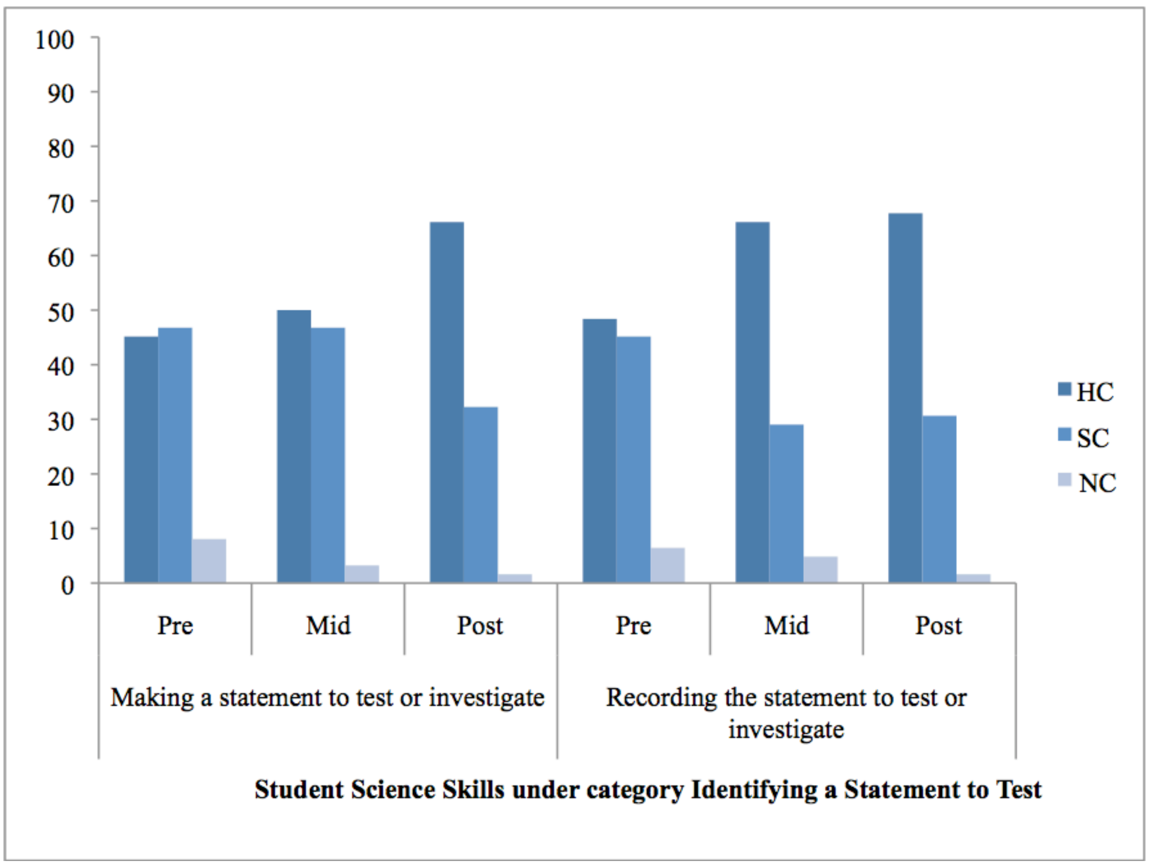

Figure 10. Percentage of Student responses per science skill category for each pre, mid, and post student science self assessments. (*N*=62). *Highly Confident (HC), Somewhat Confident (SC)*, and *Not Confident (NC).*

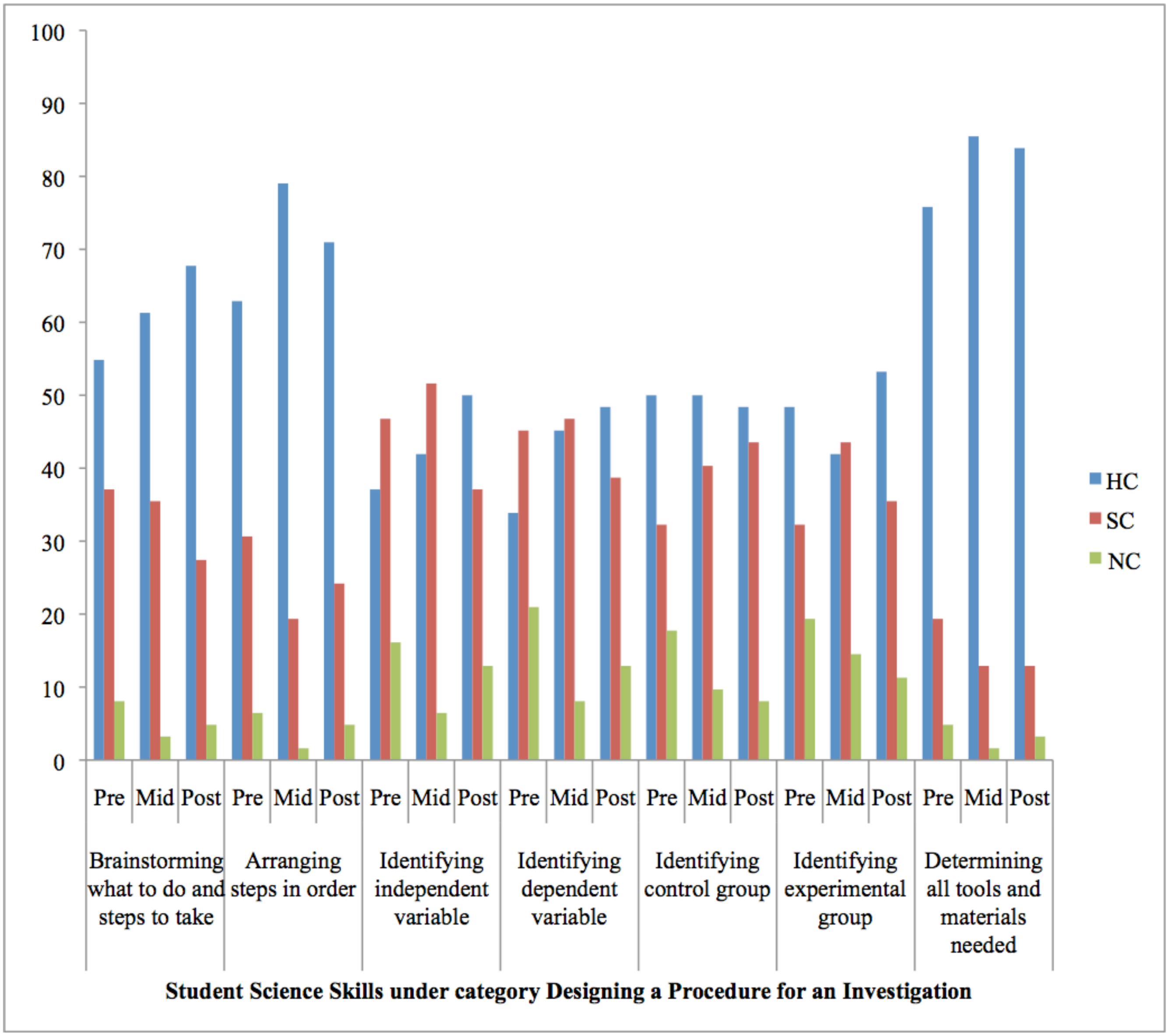

Figure 11. Percentage of Student responses per science skill category for each pre, mid, and post student science self assessments. (*N*=62). *Highly Confident (HC), Somewhat Confident (SC),* and *Not Confident (NC).*

The mid survey resulted served to monitor students during the extent of the research. The mid survey results were compared and used to chart possible progress or areas of need with science skills. The mid survey results enhanced the trend in the overall data set and illustrated students *somewhat confident* and *not confident* values decreased as *highly confident* values increased across all skill levels over the course of this research (Table 3).

INTERPRETATION AND CONCLUSION

Data results from the Student Science Survey revealed at the beginning of the study that a slight majority of the students were excited to come to a new science class while others indicated they had mixed feelings. Those student preexisting beliefs, feelings, and attitudes towards science class were perhaps echoed in the results from the first Student Science Inquiry Survey. The first inquiry survey data results revealed the majority of the students at the beginning of the year were overall somewhat confident to not confident in their abilities to do science. However, students indicated the activity they enjoyed the most in previous science classes were laboratory investigations. This was also reflected in data results of the first Student Science Inquiry Survey as the majority was highly confident in only two categories and those were related to performing lab experiments but they lacked the confidence in all other aspects of the science skills measured. The combined data from the pre surveys suggested students would benefit from inquiry based labs and lessons to increase their science skills and thereby, increase their confidence in their abilities to do science. These data helped formulate an inquiry based curriculum. Since one of the research questions was to determine if more challenging inquiry based labs and lesson would increase student motivation and academic performance, the MAPSI table was used for. The MAPSI ranking provided an unbiased method to measure a variety of laboratory investigations, activities, and lessons as more or less inquiry based for comparison purposes. The

MAPSI also provided a legitimate tool to determine and categorize the ten laboratory investigations used during this research period as more or less challenging for students. Although there was some concern student motivation would decrease with the more challenging student driven inquiry lesson and labs, data results showed the opposite occurred. More students failed to complete the less challenging teacher driven assignments. Also, as the mid and post Student Science Inquiry Surveys data revealed, student confidence levels increased across all science skills perhaps due to the student driven work. These data support the argument students engaged in scientific inquiry based learning do direct their own development of scientific skills (Krajcik et al., 1998). This was supported in the *What Helped Me Learn Genetics Survey* as students ranked inquiry based laboratory investigations as the most effective strategy used for learning genetics content.

Survey data of what motivated students to do well in their academics indicated adult feedback from parents, coaches, and teachers was important for the majority of students over any other reward. Students also reported ample help with their science work at home. Those data suggested relative quick teacher feedback and constant update of online grade book was important in terms of motivating students to perform well academically. The feedback and engagement from adults and the school community suggested the students responded positively to the awareness people cared about their individual academic success (Wentzel, 1997; Wentzel, 1998). Since students revealed adequate help at school and at home with science work, the use of more challenging student driven labs and lessons was suitable for these students. Students welcomed and responded well to working with not only their teacher but also parents in a collaborated manner in their studies (Bouillion & Gomez, 2001; Crawford, 2000). Data suggested collaboration with adults may have been an important and effective element in student motivation.

Another element that added to an increase in student motivation was the fact many of our inquiry based lessons utilized plants and animals in investigations to explore real world issues (Windschilt, 2001; Crawford, 2000). Students enjoyed the opportunity to experience nature and their environment in the classroom and this kept them motivated to come to class to observe any changes or do any tasks related to the studies. Students grew plants and conducted scientific inquiry projects for several weeks. Students investigated the use of biodegradable materials to clean up oil spills and clean water. Many animals, such as legless lizards, were used for discrepant events and misconception probes. A salt water tank and fresh water tank were kept in the classroom and stocked with native animals. Those were just a few examples of how the use of the environment motivated students and helped them take an ownership in the science classroom and increased student motivation.

In terms of relating increased motivation with an increase in academic success, most of the measurements used were perhaps not the most telling. The Biology MAP scores were used as an initial measure of science literacy among the students. Those and other successful measures of student literacy included the Student Biology Journals maintained all year. The use of student biology journals allowed me to monitor student understanding of various content materials. The materials included warm up questions related to the previous day's lessons, abilities to take and record observations, the variety and level of questions they were instructed to write down during discrepant events, and the use and proper context of biology content vocabulary. The weekly summary entries in student notebooks allowed me to the opportunity to assess whether the activities and laboratory investigations helped students make connections with the content. It seemed and the data reflected students strove to become more literate and make deeper connections with science concepts with the use inquiry based strategies (NAP, 1996; AAAS, 1993). Although this process was very time consuming, it was a beneficial tool for assessing student literacy in science and also motivation to work hard.

To determine if inquiry based activities increased academic success, a variety of traditional assessments were utilized and compared. In the end, assessment scores proved not to be the best measure of student academic success over time. Unit test grades proved not to be a good measure either since most students maintained a consistent A to B average with slight changes in grade averages throughout the course of this study. However, the ability for the majority of students to maintain a high grade point average indicated they were motivated to come to biology class and consistently work hard at their studies. Student unit test grades also indicated the use of inquiry based strategies may have helped students contextually retain information (Kirshner et al., 2006; Pillay, 1994). The variety of inquiry based strategies proved to be successful at increasing student motivation and also successful at helping students consistently perform at a higher level academically thought the course of this study. My students' high EOC scores indicated they had a lot of biology content in the long term memory and they had to the ability to recall this information on a single end of the year assessment. I attribute those successful scores to inquiry based learning. Because of inquiry based learning techniques applied in the classroom, my students were given the opportunity to study the same or similar material in several different ways. They were able to make deeper connections which helped them academically.

VALUE

To enhance my data results, I would have liked to have surveyed biology honors students that I did not teach this year. I was allowed by my principal and district to deviate from the curriculum map for these research purposes but other teachers in the district were strictly following the teacher planning instructional units for biology (Appendix F). Although my students' midterm, benchmark test, and weekly computer based test averages were inconsistent, they were among the highest of our county's students who also took the very same assessments. My students scored the highest in the county on their biology end of course exam as well (Phillip Shaw, personal communication, June 6, 2011).

An unexpected benefit with the use of student journals included how students used the summary entries. Many used them as a diary of what their week was like in biology class. They indicated strong and weak points of lessons, asked questions, made comments, indicated to me any struggles. Many of the comments were positive and thoughtful. The use of the student journals allowed me to dialogue with my students on a more personal level. I always commented back to them with positive, motivating notes which they seemed to appreciate. Equally important to me, students made it clear which teaching methods students liked or disliked. This helped me formulate inquiry based lessons that motivated students. I think students appreciated and responded well to a teacher who added a variety of inquiry based learning methods into the science curriculum. The use of inquire based learning, discrepant events, misconception probes, student driven laboratory investigations, enhanced the learning environment.

In conjunction with the surveys, students were able to access and monitor a weekly updated online biology grade book. I feel these tools gave students the opportunity to take ownership in their own educational experience. Over the course of the school year and especially during the duration of this research, students were motivated to strive for and maintain a high level of academic success in biology class.

I do feel the more student driven inquiry based laboratory investigations challenged students more so than the teacher driven labs. The inquiry based labs challenged students to come up with testable questions, design experiments, and present their own data and findings. Although my students struggled and were more challenged with inquiry based labs, they worked harder and did not give up as easily. We had ongoing plant growth inquiry labs and I allowed students to work and keep science fair projects in the classroom. This added a sense of ownership in the classroom and students were excited to get to the classroom to observe and tend to projects. We would work on these inquiry based labs on "Science Fridays." This added a break in the weekly routine in addition to hands-on lessons in which the students were the scientists.

Additionally, the more student driven inquiry based labs allowed me time to work with students as a colleague instead of instructor. We worked on developing hypotheses, making observations using scientific tools, looking for materials, and researching together. Often, students came in during their lunch hour and we would work on data sets together and look for patterns. My background as a research scientists served my students as we worked side by side on various investigations. I was also able to put them in contact with other scientists for collaboration purposes. This experience helped motivate students and also helped students develop higher confidence levels in their abilities to so science, as reflected in their self assessment surveys.

The use of inquiry based lessons in my biology classroom proved to be successful. Students may not have academically improved but they did maintain a high grade average during the course of this research and the school year. The best measure, students felt they improved over time with the use of inquiry based lessons and instruction. The variety of inquiry based instruction allowed me to be more creative and thoughtful in my planning for biology lessons. Through action research, I developed good repo ire with my students as we communicated often and worked together as investigators. I cannot imagine teaching any other way or having a better educational experience than I had this past school year due to this research. My data results indicated to me, the methods and strategies I used in my classroom enhanced the learning environment and motivated my students to consistently perform to the best of their abilities. Through this action research, I learned it is important to create and to maintain an educational environment in which curiosity and community are encouraged throughout the learning experience. I also learned as an educator I could encourage fun, excitement, and love of learning without sacrificing a vigorous biology curriculum.

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APPENDICES

APPENDIX A

THE MATRIX FOR ASSESSING AND PLANNING SCIENTIFIC INQUIRY

The Matrix for Assessing and Planning Scientific Inquiry*

Increasing in complexity →

1. *Generating scientifically oriented questions*

Students do not contribute to the investigation questions; teacher provides questions and/or other resource with questions.	Students make revisions to the questions provided by teacher or resources.	Students develop their own questions for investigation.

2. *Making predictions or demonstrating the formulation of a hypothesis before investigation*

Students do not create predictions or hypothesis; teacher or resources provide these.	Students modify predictions or hypothesis given by the teacher or resources.	Students develop their own predictions and hypothesis for investigation.

3. *Designing and conducting research study*

   Subprocesses

Designing investigation procedure	Students do not design; teacher or resources provide these.	Students make some contributions.	Students design most of the procedures with limited help from teacher.
Identify variables	Students do not choose variables; teacher or resources provide these.	Students choose variable but have limited rationale for choices.	Students have thoughtful, scientific rationale for choices of variables.
Identifying experimental and control groups	Students do not choose experimental or control groups; teacher or resources provide these.	Students design some of the limits of the experiment.	Students give focused attention to the design of controls and conditions.
Data collection and organization of data	Students do not collect data; teacher or resources provide these.	Students collect data with some input and help from teacher or resources.	Student collect and organize data with very little help from teacher or resources.

4. *Explaining results*

   Subprocesses

Use of simple summary statistics,	Students do not analyze data;	Students do some of the analyzes with	Students do the majority of

calculations, and graphing of data	teacher analyzes data.	teacher help.	analyzes with limited teacher input.
Identifying evidence based on analyzed data	Students do not identify evidence from data; teacher identifies evidence.	Students identify some evidence from data; teacher identifies most of the evidence.	Students identify evidence from data with limited teacher input.
Checking findings for accuracy, addressing experimental errors	Students do not address accuracy or error analysis; teacher checks for accuracy or error analysis.	Students address some accuracy or error analysis; teacher checks for the majority accuracy or error analysis.	Students address accuracy or error analysis with limited teacher input.
Connecting evidence with scientific knowledge	Students do not strive to make connections with scientific knowledge; teacher or resources provide connections.	Students make some connections with scientific knowledge; teacher or resources provide majority of connections.	Students make connections with scientific knowledge with limited teacher input.
Communicating results (oral or written)	Students do not communicate results; teacher communicates findings to students.	Students communicate some results; teacher communicates the majority of findings to students.	Students communicate results with limited input from teacher.
Addressing additional experimental questions or real-world applications	Students do not address additional questions or application; teacher or resources address additional questions or applications.	Students address few additional questions or application; teacher or resources address most of the additional questions or applications.	Students address additional questions or application with limited input from teacher.

Based on Grady, 2010, pgs. 34-35

APPENDIX B

THE STUDENT SCIENCE SURVEY

The Student Science Survey

1. Are you excited and motivated to come to science class? Explain.
2. How do you feel about your abilities to “do science”?
3. What kind of activities do you enjoy in science class?
4. Are you motivated by outdoor science labs or indoor science labs?
5. How do you feel when you complete an assignment or project or lab?
6. Do you feel you have enough help in science class?
7. Do you feel your classmates help or hurt your science studies? Explain.
8. Do you receive enough feedback on assignments, projects and labs from adults in your life (teachers, coaches, parents)? Explain.
9. Do you feel you should be rewarded with things (candy, toys, money) for completing science work to the best of your abilities?
10. Is there anything else you need me to know?

APPENDIX C

STUDENT SCIENCE INQUIRY SURVEY*

Student Science Inquiry Survey

Stage of Inquiry	**I am very confident in my abilities**	**I am somewhat confident in my abilities**	**I am not confident in my abilities**
Exploring			
Making observations			
Recording observations			
Taking careful notes			
Drawing illustrations, labeling illustrations			
Questioning			
Making questions based on observations			
Creating scientific investigation type of questions			
Brainstorming “what if…” possibilities for experimenting			
Identifying a statement to test			
Making a statement to test or investigate			
Recording the statement to test or investigate			
Designing a procedure for an investigation			
Brainstorming what to do and steps to take			
Arranging steps in order			
Identifying independent variable			
Identifying dependent variable			
Identifying control group			
Identifying experimental group			
Determining all tools and materials needed			
Using the investigation plan			
Obtaining materials needed for investigation			
Following written procedures			
Following safety protocols			
Respectively communicating with others			
Assuming leadership role			
Making constructive contributions to the group			
Collecting Data for Evidence			
Gathering quantitative and qualitative data			
Making accurate measurements			
Organizing data into charts and graphs			

Plotting data on graphs			
Describing patterns in variables			
Drawing a conclusion based on data			
Analyzing results using calculations			
Proving or disproving a hypothesis			
Communicating results of an investigation			
Displaying procedures, data, conclusion			
Writing investigation and all findings in a lab report			
Orally communicating investigation and all findings in a lab report			
Researching for scientific knowledge related to investigation			
Identifying valid or credible resources			
Using peer reviewed journals			
Citing resources			
Extending investigations			
Addressing additional questions to investigate			
Real-world application of your data findings			
Communicating with scientists			

Based on Llewellyn, 2005, p. 121.

APPENDIX D

WHAT HELPED ME LEARN GENETICS STUDENT SURVEY

What Helped Me Learn Genetics

Rank the below items in order of 1-17 based on how much the item helps you understand what we study in Biology class. Most helpful = 1 and least helpful= 17.

___ Reading and comprehension worksheets

___ Vocabulary crosswords or word searches

___ Note taking/ Lecture

___ Labs in which you design the investigation

___ Labs in which you are given step-by-step instructions

___ Labs to introduce a topic

___ Labs after note taking and introduction to a topic

___ Written lab reports

___ Drawing or creative activities

___ Videos about the topic

___ Review games

___ Gizmos and webquests

___ Reading the textbook the night before a quiz or test

___ Rewriting or rereading my notes each day

___ Study Guides

___ Warm ups

___ After school study groups

APPENDIX E

SCIENCE SKILLS ASSESSMENT*

Science Skills Assessment

Start Date __________ Student Name_________________________________

Scale 1, 2, 3 (1 = best; 2 = adequate; 3 = not met)

Lab Activity	**Date Completed**	**Questions, Predictions, Hypothesis**	**Lab Skills & Conduct of Experiment**	**Observations & Data Recording**	**Interpretation of Data & Experiment**	**Responsibility, Initiative, Work Habitats**	**Notes**

**Based on Hofstein, Lunetta, and Gidding,s 1981.*

APPENDIX F

EXEMPTION REGARDING INFORMED CONSENT

Exemption Regarding Informed Consent

I, Phillip Shaw, Principal of McCracken School, verify that the classroom research conducted by Kathryn R. Madden is in accordance with established or commonly accepted educational settings involving normal educational practices. To maintain the established culture of our school and not cause disruption to our school climate, I have granted an exemption to Kathryn R. Madden regarding informed consent.

Phillip Shaw
(Signed Name)

[illegible]
(Printed Name)

11/11/10
(Date)