

INCREASING STUDENT MOTIVATION AND CONTENT KNOWLEDGE
THROUGH INQUIRY BASED TEACHING IN BIOLOGY

by

Zoe Dawn Lamm

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

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2017

©COPYRIGHT

by

Zoe Dawn Lamm

2017

All Rights Reserved

DEDICATION AND ACKNOWLEDGEMENTS

I would like to thank all the amazing people who have given me advise on this project, especially everyone who has proof-read it for me. But most of all I would like to thank my husband Roger, and children Chris and Katie, without their support and taking care of everything else around the home, while I worked on this I would never have the time to do what needed to be done.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND1

2. CONCEPTUAL FRAMEWORK.....3

3. METHODOLOGY11

4. DATA AND ANALYSIS17

5. INTERPRETATION AND CONCLUSION28

6. VALUE.....32

REFERENCES CITED.....36

APPENDICES40

 APPENDIX A IRB Exemption.....41

 APPENDIX B Survey of Science Related Attitudes43

 APPENDIX C Pre / Post Test Questions.....47

 APPENDIX D Minnesota Comprehensive Assessment (MCA)
 Sample Questions.....57

 APPENDIX E Post-lab Notebook Reflection Questions.....60

 APPENDIX F Student Engagement Observation and Question Form.....62

LIST OF TABLES

1. Comparison of Traditional and Inquiry Activities.....	12
2. Data Triangulation Matrix	17
3. Wilcoxon Signed Test Results	20

LIST OF FIGURES

1. Pre- and Post-Test Results	18
2. Normalized Gains for Each Unit.....	19
3. Scores on the Minnesota State Science Assessment.....	22
4. Answers to student pre- and post-survey	24
5. Student Learning Style Preference.....	25
6. Missing Assignments per Unit.....	27
7. Average Score on Post-Test.....	28

ABSTRACT

In this investigation a variety of inquiry activities and labs were implemented in two different units of instruction, and compared to two traditionally taught units with the purpose of improving biology content knowledge and student motivation. Student attitude and motivation was measured using a student survey, student notebook reflections, and teacher observations. Biology content knowledge was measured using pre- and post-tests, and state standardized test scores. An improvement in student attitude and motivation was observed during the inquiry activities, but no statistical difference in student content knowledge was observed between the traditional units and inquiry units on classroom tests. Students showed significant improvement on the state standardized test. Most noticeable was the improvement in the students who had previously failed to meet the state standards, with a large gain in their application of science practices.

INTRODUCTION AND BACKGROUND

I currently teach life sciences in Caledonia, Minnesota, where I am the only high school biology teacher. Every student in the school will at some point in their high school career take Biology I with me. I also am responsible for teaching the electives anatomy and physiology, and Biology II each year. I teach forensic science and zoology as electives on alternate years. A typical Biology I section has anywhere from 16 to 30 students enrolled and is taught on a block schedule for one semester during a student's tenth grade year (Caledonia Public Schools, 2016).

During my 14-year career as a middle and high school life science teacher I have taught a wide variety of students in a diversity of settings but my aim has always been the same. I want students to enjoy science, to see science as amazing and fascinating like I do, and because of this interest have the motivation and engagement needed to learn science content. For eight years I taught inner city and suburban students in Charlotte, North Carolina before moving to rural southeast Minnesota. Despite the wide differences in location, I have found that most students are basically the same. They are still turned off of science at an early age before they ever reach my classroom. Students see science as difficult and complex with many strange vocabulary words and rules. This creates an uphill battle I have to fight against low motivation and a defeatist attitude.

The development of my action research-based project question came out of my own observations and frustrations with students in my classroom. When asked, students say that the best part of science class is doing labs; however many students struggle to handle the independence lab work requires, wanting me to give them help at every step.

My answer has always been to provide very detailed, cookbook style labs, with every step of the lab clearly outlined, the data tables ready to be filled out, and a few questions to be answered at the end. It has always frustrated me that students complete the labs, and seem to enjoy the process of having a hands-on activity working in a group, but the amount of learning going on is limited. They struggled to make the connection between the lab activity and the topic being taught, which led to frustration with science class, complaints about how hard everything is, and general low achievement. This led me to wonder if I could use inquiry based teaching methods to increase biology content knowledge through increasing student motivation towards learning science. I had previously avoided inquiry in Biology I due to the large class sizes and time constraints of completing the curriculum before the standardized test, although it is something I enjoy in Biology II.

When inquiry-based teaching strategies were utilized, lab work became more relevant to students, which helped with their active participation and motivation. Once they were more activity engaged in their learning experience the lab should have more productively taught and reinforced the biological concepts. By allowing students the opportunity to make mistakes rather than giving them all the cookbook style instructions, students might have experienced frustrations at first, but they should have developed skills to help them learn how to learn science. By including self-reflection after each lab activity, students were made to think back on what the lab had taught them and how the lab related to biology content. All of these factors led me to develop the focus of my classroom research as, *Do inquiry based teaching practices improve scientific literacy*

and student motivation in high school biology? In addition the following sub-questions were researched.

1. How does teaching using different inquiry strategies improve understanding of biological concepts?
2. How does teaching using different inquiry strategies improve student motivation and attitudes towards biology and science in general?
3. How can inquiry increase student participation during lab activities?

CONCEPTUAL FRAMEWORK

In 450BC, Confucius said, “Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand.” Today, we still learn best by being active participants in our education. Inquiry based learning is nothing new. The idea dates as far back as John Dewey, who in 1916 was an early proponent of experimental education and hands-on learning (Crawford, 2000). Over the past two decades, inquiry, while applicable in many educational disciplines, has become a buzzword within many science departments (Trowbridge, Bybee & Powell, 2000; Lawson, 2000). Inquiry is often given as the answer to all science classroom problems, whether those problems are teaching science literacy, covering science standards, differentiating work to reach all students or assessment ideas. Inquiry has come to refer to the activities used during class to help students become scientifically literate. In reality inquiry is more than just strategies used during class time. Llewellyn models inquiry as a three-legged stool, where the three legs refer to the doing, knowing and teaching aspects of inquiry (Llewellyn, 2012).

There are many different definitions for inquiry including doing science, hands-on science, and real-world science (Crawford, 2000). One source reported 14 different uses of the term inquiry, all of which are valid (Biological Sciences Curriculum Study, 2006). However, when it comes to the science classroom, inquiry should reflect the methods that scientists use in their research. Inquiry should be students modeling what scientists do (National Research Council, 1996; Luckie, Aubry, Marengo, Rivkin, Foos, & Maleszewski, 2012; Kremer, Specht, Urhahne, & Mayer, 2014; NGSS Lead States, 2013).

Inquiry based teaching is typically divided into two groups. The first is guided inquiry, where the teacher provides scaffolding to assist the student in developing their investigation. The second is open inquiry, where the teacher acts as a collaborator. In reality there are many levels of inquiry between guided and open that a teacher can use to teach students the inquiry process (NRC, 2000; Colburn, 2008). When implementing inquiry for the first time, teachers typically should start with guided inquiry in order to model the inquiry process and to avoid students shutting down from lack of knowledge and from frustration. As students build their knowledge and thinking skills they can be transitioned from guided to open inquiry by gradually reducing the scaffolding provided (Colburn, 2008; Fay & Bretz, 2008; NRC, 2000; Roehrig & Luft, 2007).

Unfortunately, the ideal of students undertaking independent student-driven laboratory research while in high school is not the normal situation (Bencze & Bowen, 2009). In the typical high school science classroom, an experiment is completely removed from a real scientific investigation; the teacher has decided what to investigate,

and how to perform the investigation (American Association for the Advancement of Science, 1993). Students are not expected to have much independent thought. Too many students sit passively and are never asked to make sense of the content being delivered to them by their teacher (Tweed, 2009; Lord & Orkwiszewski, 2006). They are so used to this situation that even when they have performed the experiment correctly they will reject their own data if it does not match their textbook, the internet, or facts presented to them by their teacher (McDonald, 2012).

In an attempt to increase scientific literacy and alter the typical science classroom, the National Science Teachers Association published a position statement on scientific inquiry recommending that all science teachers plan for and implement curriculum that “provides students with the time, space and resources needed for learning science through inquiry” (NSTA, 2004, p.2). The most recent advancement in the implementation of inquiry-based science for all is the Next Generation Science Standards, with one of their dimensions of science learning being science practices. Science practices extend, and more fully explain, the concept of scientific inquiry, while providing some detailed performance expectations to guide teachers in curriculum design. For example in science dimension one, it is expected that all students engage in the scientific process of inquiry by asking questions, and designing and carrying out investigations (NGSS Lead States, 2013). By teaching students content knowledge through an inquiry method, teachers enable students to connect their learning to previous experiences, to modify previously held beliefs and construct new knowledge as independent thinkers. Inquiry is a way of

making teaching student-centered (Llewellyn, 2012; Trowbridge et al. 2000; Luckie et al. 2012; Lord & Orkwiszewski, 2006; NGSS Lead States, 2013).

Through the use of inquiry, rather than the memorization of discrete, unconnected, and forgettable facts, students will become lifelong scientifically literate citizens (AAAS, 1993). There is a need in America for a workforce highly trained in the skilled areas of science, technology, engineering and mathematics, with too few students currently entering these fields (NGSS Lead States, 2013). To be prepared for these careers students are going to have to be good critical thinkers. Schools today are pushing towards increasing the amount of inquiry taught in the high school classroom as a means of students acquiring critical thinking and scientific literacy skills (Noddings, 2008). In 1996 the National Research Council, as part of its national science education standards, developed a set of guidelines to assist teachers and schools in the move from traditional direct instruction and cookbook style lab activities to inquiry based science, in order to achieve the long-term goal of national scientific literacy (NRC, 1996). These standards have become integrated into the Next Generation Science Standards, the latest attempt to improve how science, technology, engineering, and mathematics is taught, and create a workforce with relevant skills and knowledge for the future of our country. A central idea behind the science and engineering practices in the NGSS is the idea that “students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry” (NGSS Lead States, 2012, Appendix F p.1). The practices also acknowledge that inquiry needs to be rooted in content knowledge taught by a knowledgeable teacher. With all our advances in science over the last 15 years the basic premise of the original

science standards still holds true. Students learn science in the same way that scientists develop their knowledge, through experimentation and active engagement in the scientific process (NGSS Lead States, 2013).

Currently most students in United States high schools never have the chance to undertake a major inquiry style investigation, (Mascarelli, 2011; Harmon, 2011). For example, many students are put off competing in science fairs, with the number of high school students taking part on a slow decline. That decline is due to both students and teachers. With students the decline is attributed to the many demands on their extra-curricular time. Most teachers cite all the testing and standards to be met as the reasons they feel unable to devote significant classroom time to such projects (Harmon, 2011). Despite this, research at the elementary level has shown that test scores in all subject areas are increased through devotion of class time to inquiry based science, such as a science fair project (Shymansky, Wang, Annetta, Yore & Everett, 2013).

Although there is a push for science teachers to use inquiry based teaching practices in their classrooms, inquiry is not always the best answer for all topics. When students need to learn a subject such as anatomy, which is a concrete, highly factual topic, the amount of time put into inquiry learning compared to didactic teaching methods does not result in a significant increase in knowledge. In contrast, when students are taught abstract topics such as evolution, physiology, behavior or ecology utilizing inquiry methods, studies show they are able to make more meaningful connections with the material (NRC, 2000; Timmerman, Strickland, & Carstensen, 2008; Kremer et al. 2014).

Inquiry based learning does not automatically translate into higher test scores. In one study, a positive student attitude had a greater impact on student achievement than inquiry by itself. The increase in test scores from inquiry might have been attributed to the science becoming relevant and interesting to the student, and as such motivation might be the more important contributor to the classroom from inquiry-based lessons (Hung, 2010). The Next Generation Science Standards also indicate that inquiry can be an important motivator to continued study, and therefore aid in learning (NGSS Lead States, 2013). When students are actively engaged in learning science through inquiry methods they are using a variety of different skills, including physical, intellectual and social skills (Trowbridge et al., 2000; Roehrig & Luft, 2007; Lord & Orkwiszewski, 2006; NGSS Lead States, 2013). Having to use a combination of these skills more fully engages the student in the activity, and engages more students' interest than traditional more limited methods (MacIver, Young & Washburn, 2001; Lord & Orkwiszewski, 2006). In studies where students were introduced to inquiry then given a quiz, they scored lower on the quiz than with traditional teaching, but still self-reported a higher level of engagement and a better understanding of the concepts, along with a desire for more inquiry based activities (Booth, 2001). However it is a misconception to automatically assume that engagement and participation in inquiry will guarantee that learning is occurring (NRC, 2000).

Students tend to be more motivated to learn when they collaborate with teachers in guided scientific inquiry based lessons and activities (Crawford, 2000; MacIver et al., 2001; Lord & Orkwiszewski, 2006). The frequency with which students are given the

opportunity to engage in inquiry is strongly related to how motivated students feel in the science classroom (McIver et al., 2001). When first presented with inquiry activities students often feel frustrated, not knowing what they are supposed to do, and complain about having to think. As inquiry becomes a regular part of the curriculum and the teacher becomes better skilled at asking questions, these issues diminish (Booth, 2001; Lawson, 2000). These issues illustrate the need for inquiry to be used as a regular component of science education from an early age, and for inquiry teaching skills to be further incorporated into science teacher training programs (AAAS, 1993; Trowbrige et al., 2000; NRC, 2000).

Although it has been recommended for many years now that all science teachers embrace inquiry in their classrooms, the day to day details about how to implement inquiry are often left to the imagination of the overworked and overwhelmed teacher, leading to many challenges, much frustration and a lack of success (Crawford, 2000; Roehrig & Luft, 2007). Some of the major concerns reported by teachers regarding implementing inquiry are the amount of time it takes in an otherwise already crowded curriculum, the fear of lower test scores, classroom management issues and the lack of resources (Booth, 2001; Fay & Bretz, 2008; Lawson, 2000). These concerns, while genuine, are often unfounded once inquiry is established in the classroom. Studies have indicated that through the use of fewer, long-term inquiry based investigations, students learn more content than with many short cookbook or demonstration style experiments (Luckie et al. 2012; Lord & Orkwiszewski, 2006; NGSS Lead States, 2013).

In order to help teachers prioritize their choice of inquiry activities and to select the most relevant activity several simple rubrics are available to help evaluate the large range of choices. The Analyzing Instructional Materials Process scoring rubric produced by Biological Sciences Curriculum Study is easy to use and free to download (Fay & Bretz, 2008; BSCS, 2006). There are also several quality inquiry based curricula available for teachers to use such as the BSCS textbook series and 5E curriculum model. The use of these instructional materials increases the likelihood that students will be focused on learning the correct materials, but does not guarantee that students will be engaged in inquiry, unless a skilled teacher is facilitating the lesson (NRC, 2000). Teachers who are resistant to implementing inquiry can first make small changes to their traditional cookbook labs to make them more open ended, as an intermediate step (Peters, 2005).

While there might be resistance to change initially, studies indicate that in the long-term inquiry based learning is to the benefit of both the students and the teacher (Luckie et al. 2012). Students develop a better understanding and enjoyment of science, which reduces the traditional day-to-day frustrations the teacher has in the classroom (Trowbridge et al. 2000). There are many quality resources available for teachers to use in their transition to inquiry based teaching practices. Many of those resources lay out the steps of for classroom activities clearly and simply, with very little creativity or time needed by the teacher. In addition, by being student centered an inquiry-based classroom should require less direct teacher instruction. As direct instruction decreases there is more

time for student learning to occur because students become self-motivated learners, able to work independently and make more decisions for themselves (McIver et al., 2001).

METHODOLOGY

Inquiry-based instructional methods were implemented at Caledonia High School with 26 sophomore biology students between February and May 2017. The treatment consisted of implementing a mixture of several different inquiry based curriculum models. These included *Regenerative Medicine in the Classroom* (Beermann & Limberg, 2015) based on the Biological Science Curriculum Models 5E learning cycle, *What can I learn from worms?* (Project Neuron, 2012) curriculum unit, *Biology Inquiries Standards-Based Labs, Assessments, and Discussion Lessons* (Shields, 2006) and NSTA's *Argument-Driven Inquiry in Biology* (Sampson et al., 2014), to transform traditional biology units into guided inquiry based instruction. In addition, a semester long independent guided-inquiry project was implemented within the classroom setting. The students had the opportunity to work individually or with a partner for this project.

To determine the impact of inquiry-based teaching strategies on student motivation and content knowledge, baseline numbers were established prior to implementation. Quantitative and qualitative data was collected at the beginning of the semester, at the beginning and end of each unit, and at the end of the semester. Observations were made with questioning done throughout the project. Two units were selected as non-treatment, to be used for comparison and taught in a traditional method of lectures, guided practice through worksheets and labs. These were the units on biochemistry, and cell structure and physiology. Mixed between the non-treatment units

were the inquiry units. Two of these units served as the treatments, these included the nature of biology, and cell reproduction.

For each unit, students undertook activities designed to introduce, teach or reinforce the subject matter (Table 1). All units still received some direct instruction in the form of teacher lecture, but the amount was reduced during the inquiry unit, and typically happened when students started to show frustration, or when all asked similar questions. In all units, students were provided with note packets and review questions. For the non-treatment classes, the note packets matched the teacher lectures and had completion checkpoints for student understanding. For the inquiry units, students were provided with the notes for background knowledge and the review questions as a study guide for the post-test. Content knowledge was reviewed the day before the post-test for both the non-treatment and treatment units.

Table 1
Comparison of Non-Treatment and Treatment Activities

Unit	Activity	Traditional / Inquiry	Curriculum Source
The Nature of Biology	Termite Trails	Inquiry	Biology Inquiries
	Is it alive?	Inquiry	Modified from Biology Junction
Biochemistry	Chemical tests for biologically important molecules (CT)– Part I	Traditional	Aurum Science
	CT – Part II Identify unknowns	Guided Inquiry	Aurum Science
	CT – Part III Enzymatic Digestion	Traditional	Aurum Science
Cell Structure and Physiology	Cell Comparison Lab	Traditional	Own design

	Cell Structure and Function Worksheet	Traditional	Own design
	The egg and osmosis	Traditional	Own design
	Dialysis tube lab	Traditional	Modified from Brookings biology
	Do plants produce or use CO ₂ ?	Traditional	Biology junction
	Yeast fermentation lab	Traditional	Aurum Science
Cell Reproduction	Planarian regeneration	Inquiry	Regeneration in the classroom and project neuron
	Onion root tip mitosis	Inquiry	Aurum Science and Biology inquiries
	Lab 19: Meiosis	Inquiry	Argument-driven inquiry

For the independent-inquiry project, students were asked to create a research topic based on their own interests, which they used to investigate within the classroom setting. Time was provided on a weekly basis for the project and students were guided through the process of how to conduct research, develop a procedure, and conduct their own experiment. When students chose projects that required equipment they were unfamiliar with, such as gel electrophoresis, students were taught basic experimental protocols as a small group. Students were given the opportunity to do pilot studies for their procedures and obvious errors that would cause experiment failure were not initially pointed out. Students were encouraged to brainstorm problems they encountered and to modify and re-do their experiments based on their issues and results. All students had to present their findings in the form of a poster presentation gallery walk to the rest of the class, with other staff from the school invited to come and view the students' research. 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).

To collect data on student attitudes towards science classes, lab work and inquiry-based work in particular, students completed the Survey of Science Related Attitudes before and after the treatment inquiry units (Appendix B). This survey was administered digitally through Google forms. Students answered a mixture of positively and negatively phrased questions. The survey was scored on a Likert scale. For positive questions the scale used was *strongly disagree* (1) *disagree* (2), *agree* (3) *strongly agree* (4), and for negative questions *strongly disagree* (4) *disagree* (3), *agree* (2) and *strongly agree* (1). The questions were grouped as attitude towards inquiry, student enjoyment of science lessons, and student learning style preference. The percentage of students answering in each Likert category was calculated. Pre- and post- survey answers were compared to look for an increase in number. Individual student scores were also totaled up and means calculated. Pre-survey scores were compared to post-survey scores to look for an improvement in individual student attitude towards science, and biology class. Survey scores were analyzed for significance using the Wilcoxon signed rank test.

Four non-Likert questions were also included on the survey to assess if students perceived inquiry teaching methods as helping them to learn biology content knowledge. Students had to answer open ended questions designed to probe deeper into their understanding of why they perform lab assignments and what knowledge they gain during those lab assignments. Answers were analyzed for general trends, and coded as either *positive*, *conditionally positive*, *conditionally negative* or *negative* answers. The

number of each category was tallied, then pre-treatment answers were compared to post-treatment answers to look for an improvement in student understanding of the purpose of lab work, and the benefits of inquiry.

At the beginning and end of each instructional unit, students were administered the appropriate Pre/Post Unit Test to determine if the instruction achieved the aim of students learning the biology content through inquiry teaching methods (Appendix C). Both the pre- and post-test were administered using the school-learning platform, Schoology. Results from Schoology were directly exported into Excel. Pre- and post-test results were analyzed by comparing the change in each students' score. The mean and normalized gain were calculated and box and whisker-plots drawn to look for a significant difference in student knowledge. Normalized gains of less than 0.3 were considered low gains 0.3 to 0.7 was considered a medium gain, and normalized gains greater than 0.7 were considered high gains (Hake, 1998).

At the end of their 5th 8th and 10th grade years, students in Minnesota take the Minnesota Comprehensive Assessment (MCA) in Science (Appendix D). To look for an improvement in general science literacy, student scores from their 10th grade MCA were compared to their 8th grade MCA scores. This was the last time the science MCA was administered to the same group of students. Scores were reported electronically by the state on a scale score, and assigned as either *exceeds standards*, *meets standards*, *partially meets standards*, or *does not meet standards*. Approximately half of the 10th grade MCA test is based on the application of general science literacy and half on the application of biology content knowledge. Scores were analyzed by comparing the

change in each student's score using a Wilcoxon signed-rank test. The mean and normalized gain were calculated and histograms were drawn to look for a significant change.

To determine the effectiveness of inquiry based activities on student understanding of biological concepts, students were asked to reflect in a science notebook post-lab about what they had learned, as well as how confident they felt with the material (Appendix E). All answers were analyzed for general trends, and key phrases noted. Data was graded according to a rubric and color coded for ease of analysis. The rubric used was, the student reflection showed they *did not understand* (1), student had *partial understanding* (2), or student *understood the content* (3), then the student indicated they were *confident in the material*, they were *confident in some of the material*, or *not confident*.

During treatment activities' students were observed for their level of engagement and participation (Appendix F). Observations were noted as to the number of students in a group and the type of on-task or off-task behavior observed along with the level of engagement on a scale of *outwardly negative* (1) *disinterested* (2) *passive/neutral* (3) *moderate enthusiasm* (4) to *excited* (5). Students were questioned during activities to clarify the reasons for their observed behavior and answers were noted. Results were analyzed for common themes and used as supporting evidence for the other data.

It was important in a small study such as this to have multiple data sources along with observations from the classroom. Other supplemental sources of data included formative assessment data, answers to inquiry activities and informal student questioning.

A triangulation matrix was used to track how each question and sub-questions were being studied. To minimize disruption to students, a focus within the triangulation matrix was making sure each instrument answered more than one focus question, and surveys were combined where possible (Table 2).

Table 2
Data Triangulation Matrix

Focus Question	Source 1	Source 2	Source 3
<i>Primary Question:</i>			
Do inquiry based teaching practices improve scientific literacy and student motivation in high school biology?	Survey of Science Related Attitudes	MCA Test Scores	Student observations and questions
<i>Sub-Questions:</i>			
How does teaching using different inquiry strategies improve student understanding of biological concepts?	Pre- and Post-Unit Tests	MCA Test Scores	Post-Lab Notebook Reflection
How does teaching using different inquiry strategies improve student motivation and attitudes towards biology and science in general?	Survey of Science Related Attitudes	Individual inquiry projects	Post-Lab Notebook Reflection
How can inquiry increase student participation and understanding during lab activities?	Pre- and Post-Unit Tests	Individual Inquiry projects	Student observations and questions

DATA AND ANALYSIS

Analysis of pre- and post- test scores for understanding of biological concepts indicated a medium normalized gain for all four units. The traditionally taught units of Biochemistry as well as Cell Structure and Function showed a medium normalized gain of 0.48 and 0.56 respectively ($N=26$). The traditional Biochemistry unit showed a change in the spread of results, with the post-test results showing a greater range of answers. The first treatment unit, the Nature of Biology had a low normalized gain of 0.36, but the spread of data was greatly reduced from pre- to post-test. The second treatment unit of

Cellular Reproduction had a medium gain of 0.64, but the spread of data remained similar to pre-instruction (Hake, 1998). Over all, students gained the most knowledge during the final treatment unit, with a 40% increase in their average test scores (Figure 1).

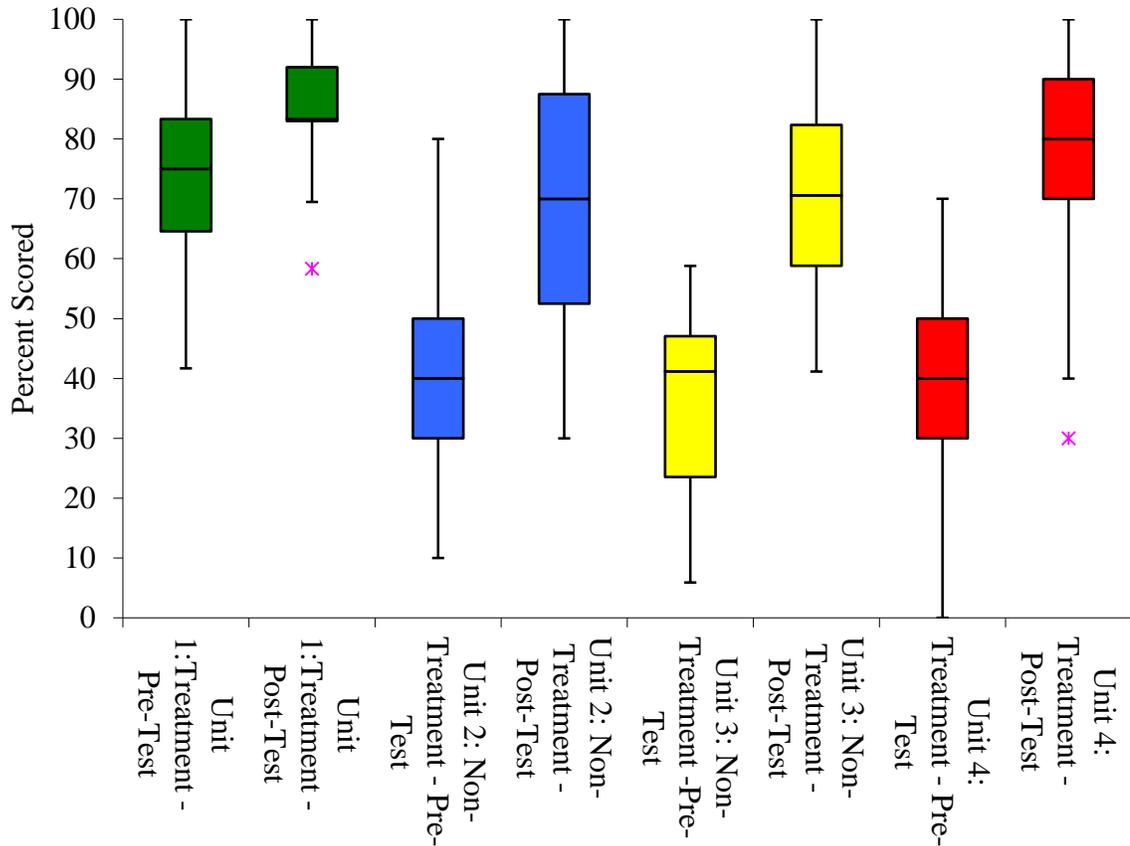


Figure 1. Comparison of pre- and post-test results, ($N=26$).

The average pre-test score for the Nature of Biology was higher than the other units at 73%, compared with 42% and 37% for the traditional Biochemistry and Cell Structure and Function units respectively, and 38% for the treatment unit on Cell

Reproduction. The average normalized gain increased for every unit taught (Figure 2).

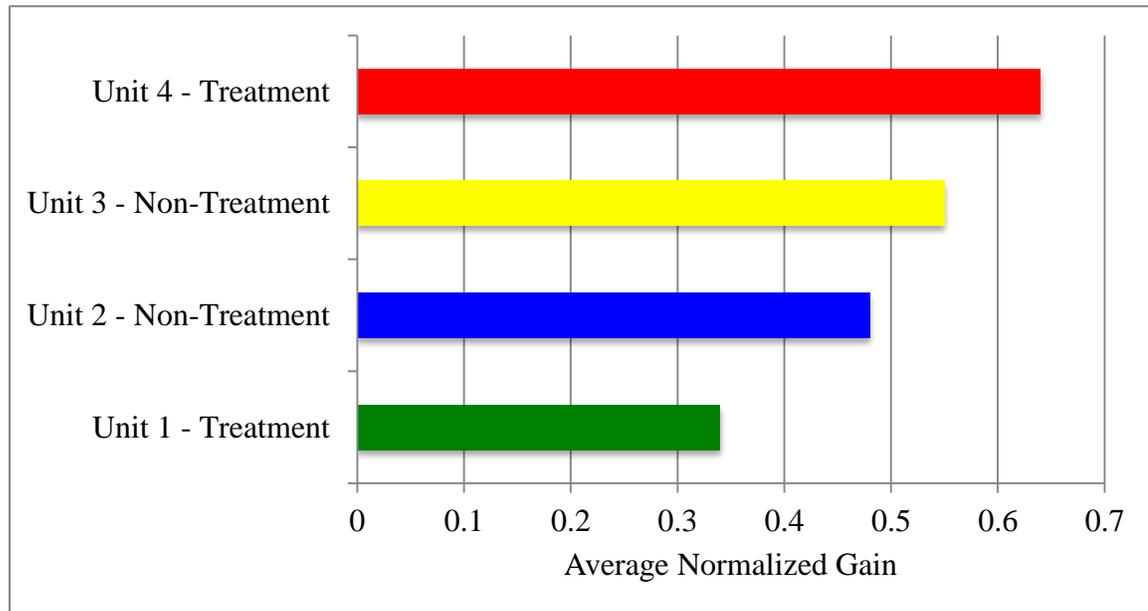


Figure 2. Average normalized gain for each unit, ($N=26$). *Note.* <0.3 Low gain, $0.3-0.6$ medium range, >0.7 high (Hake, 1998)

The results of the Wilcoxon Test analysis on pre- and post-test normalized gain data, indicated that all the test results were significant at the 95% confidence level. Comparing treatment and non-treatment groups, two thirds of the time there was no significant difference in test scores. There was a significant difference between non-treatment unit three, Cell Structure and Function, and treatment unit four, Cell Reproduction. There was also a significant difference between unit one and unit four, with students gaining more content knowledge on unit four, Cell Reproduction than on the first unit, the Nature of Biology (Table 3).

Table 3
Wilcoxon Signed Test Results. Tests performed at a significance level of 0.05.

Test Questions		Wilcoxon Calculated Value	Wilcoxon Critical Value	P Value	Significance
Treatment	Nature of Biology	8	58	<0.001	Yes
Non-Treatment	Biochemistry	0	52	<0.001	Yes
Non-Treatment	Cell Structure and Function	0	46	<0.001	Yes
Treatment	Cell Reproduction	3	58	<0.001	Yes
Treatment 1 vs. Non-treatment 1	Unit 1: Nature of Biology vs. Unit 2: Biochemistry	92	58	P>0.2	No
Treatment 1 vs. Non-Treatment 2	Unit 1: Nature of Biology vs. Unit 3: Cell Structure and Function	68.5	58	0.1<P<0.2	No
Treatment 2 vs. Non-Treatment 1	Unit 4: Cell Reproduction vs. Unit 2: Biochemistry	85.5	73	0.1<P<0.2	No
Treatment 2 vs. Non-treatment 2	Unit 4: Cell Reproduction vs. Unit 3: Cell Structure and Function	58	65	0.02<P<0.05	Yes
Treatment 1 vs. Treatment 2	Unit 1: Nature of Biology vs. Unit 4: Cell Reproduction	49.5	58	0.02<P<0.05	Yes
Non-Treatment 1 vs. Non-Treatment 2	Unit 2: Biochemistry vs. Unit 3: Cell Structure and Function	134.5	81	P>0.2	No

Note. (N=24)

Overall growth in student understanding of scientific concepts was measured using the Minnesota Comprehensive Assessment (MCA) test (Appendix D). In the eighth grade 38% of students achieved the designation of passing or *meeting* or *exceeding* standards, with 54% *partially meeting* standards, and 8% *not meeting* the standards; not

considered passing. Six percent of students scored as *exceeding* the standard. In May, after receiving instruction in both inquiry and traditional methods, the same group of students took the 10th grade standardized science test. Students showed significant gains in knowledge with 73% of students scoring *meeting* or *exceeding* the standard, 20% *partially meeting* and 7% remaining as *not meeting* the standard (Figure 3.) A significant improvement in scores, was shown from 8th grade to 10th grade using a Wilcoxon Tests with $P < 0.001$. Overall, 76% of students showed an improvement in their test scores from 8th grade to 10th grade. The improvement in scores occurred at all ability levels, with all students previously designated as *exceeded standards* improving their score. Seventy five percent of students in the *meets standards* category improved, 81% of students who *partially meet* standards improved and 67% of students *not meeting standards* showed improvement. Thirty percent of students showed dramatic improvement, increasing their scores by more than ten scale points, this included three of the five previously lowest scoring students.

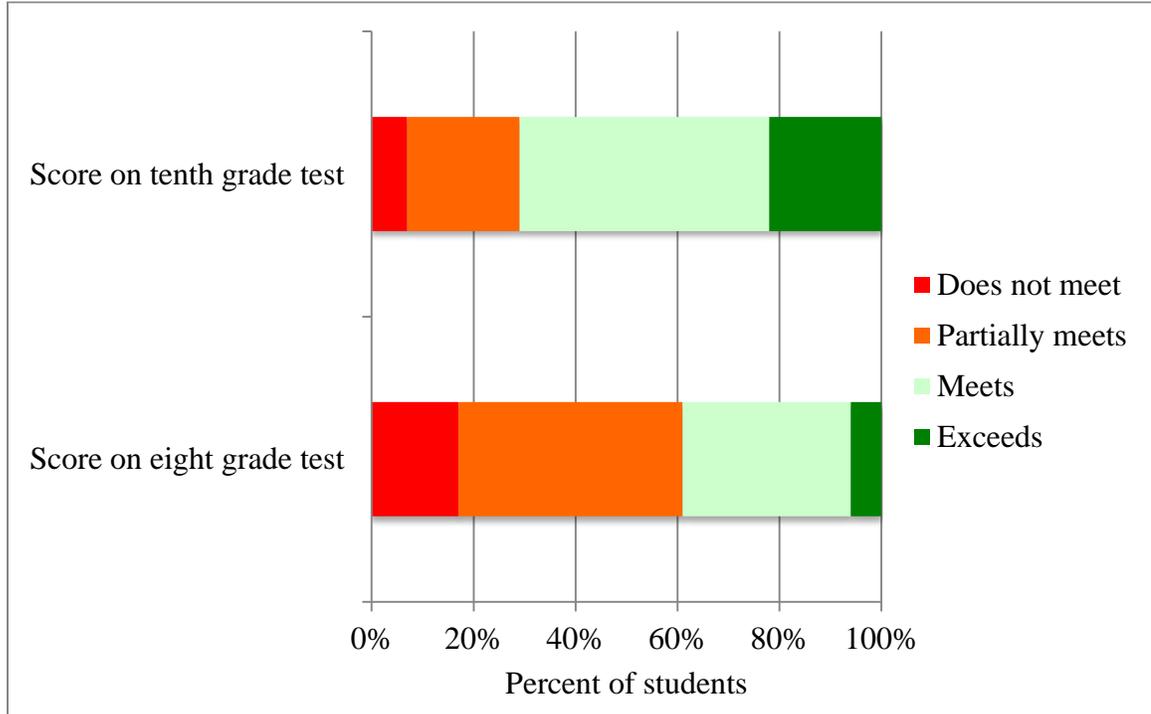


Figure 3. Scores on the Minnesota State Science Assessment, (N=26).

Analysis of the Survey Of Science Related Attitudes (Appendix B) indicated that the number of students who responded negatively towards science remained unchanged pre- and post-instruction, at eight percent. The number of students answering strongly positive increased from none pre-instruction to 14% post-instruction; Pre-instruction 92% of students had a positive attitude towards science (Figure 4). Student responses to the question, “*What do you like about science?*” supports this data. One student responded, “Getting to work hands on to come up with an answer or solution to things,” and a different student responded, “How interesting it is and doing the labs because they are fun.”

Student attitude towards inquiry also changed with instruction, with 12% more students strongly positive about inquiry after having completed the inquiry units and their own inquiry project. For the questions on student attitude towards learning through

experimentation compared with other classroom methods, both the pre- and post-survey showed that more students were positive about inquiry than were negative, with 76% of students giving positive answers of *agree* or *strongly agree* (Figure 4). Student responses to the question, “*Do you benefit from designing and carrying out your own experiment?*” supported this data. For example, one student answered, “Yes, I believe it would further my knowledge and help me to better understand the project at hand.” Another student answered, “Yes, even though it is hard for me to get started on designing the experiment.” There were also well thought out negative answers such as, “No, I can do an experiment but designing it myself probably isn’t the best idea because I over analyze and add too much and overthink every step.”

When questioned about their enjoyment of science, most students were positive. Seventy eight percent of students answered *agree* or *strongly agree* pre-instruction and 86% post-instruction. The number of students giving science the highest ranking of *strongly agree* increased 16% from 26% pre-instruction to 42% post-instruction, but the number of students strongly negative remained unchanged at 3% (Figure 4).

Most students expected to do well in science classes with 83% of students on the pre-survey answering *agree* or *strongly agree* when questioned. These results did not change much from pre- to post-instruction (Figure 4).

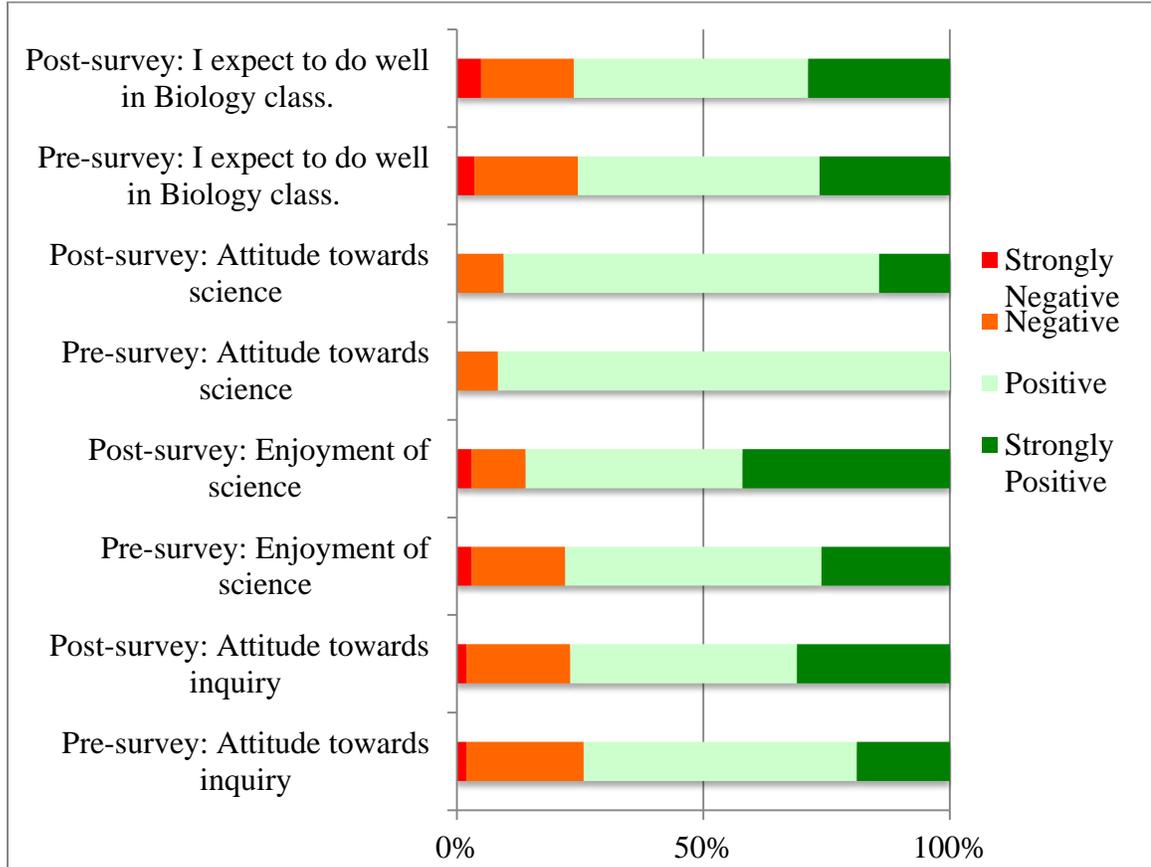


Figure 4. Answers to student pre- and post-survey, ($N=24$).

Before starting biology, students gave strong opinions about what helped them to learn. Eighty eight percent of students answered they learned best through highly structured labs, and 83% of students answered that they do not learn effectively when they have to design their own lab experiments. These numbers remained unchanged post-instruction (Figure 5). Student answers to the question, “*How well do you understand the purpose of the labs we do in class?*” support this data as most were weakly positive with 58% giving answers such as “a little,” or “For the most part I understand.” Twenty-nine percent gave strongly positive responses such as “I understand them pretty well, most of the time,” and “As long as I know what I’m doing, fine.” There were also a few negative answers such as “No well (*sic*).” Pre-instruction 21% of students indicated that they were

unclear on the purpose of some labs. Post-instruction that number dropped to 3% of students.

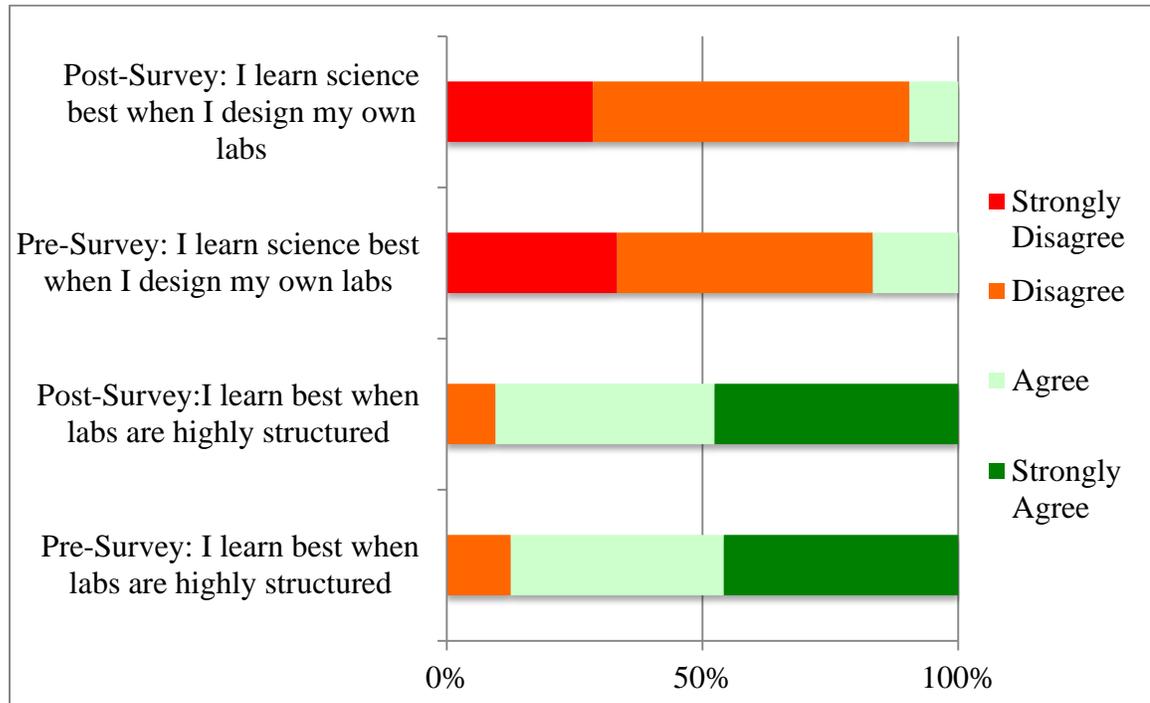


Figure 5. Student learning style preference (N=24, N=21).

When questioned, “How well do labs help you to understand biology?” only 46% of students gave positive answers, such as the student who replied, “They are my best way of learning if they are well planned out.” Twenty-one percent of students gave opinions classified as *conditionally negative* such as “I don’t know,” and “Not very much.” Post-instruction, the number of positive responses increased to 95%. One student answered, “Labs help me understand biology by allowing me to carry out experiments and see them happen firsthand.” Another student answered negatively with “50/50.”

Student participation and understanding during lab activities was measured by comparing pre- and post-test scores, reflections in student journals, and observations during individual inquiry projects. During the traditional Cell Structure and Function

unit, students started their own inquiry projects, which they worked on one day each week through the Cellular Reproduction unit and beyond. Teacher observations showed that students were always excited to work on their own projects, often asking when they would next get a chance to work on them. All students were engaged in the activities, and even when they had questions or problems, they would attempt to work through them by themselves, as well as asking for my suggestions. Teacher observations showed students appeared to enjoy the opportunity to work on a lab of their own choosing and interest. Almost everyone was on-task and participating when creating posters to present their data. This is reflected in the increase in positive attitude towards inquiry, with 12% more students indicating a *strongly positive* attitude toward inquiry (Figure 4). Two students failed to complete their inquiry project. Those two students did the lab portion, designing and undertaking their study, but failed to produce a poster of their findings. This was consistent with previous observations of these students, who were motivated by both inquiry and traditional labs, but did not complete written assignments.

The amount of missing work increased during the two non-treatment units from a low of 5% during the first treatment unit to a high of 20% for the non-treatment unit on Cellular Reproduction (Figure 6). Observation of students showed that the missing work was typically due to lack of completion on the assignment, and that students didn't find the work engaging or interesting. Observations indicated that students were more off task during non-treatment units, and when they failed to do the work during class it was not completed outside of class. When inquiry was re-introduced for unit four the amount of

missing work decreased to 13%. Teacher observations showed that students were fully engaged with these activities.

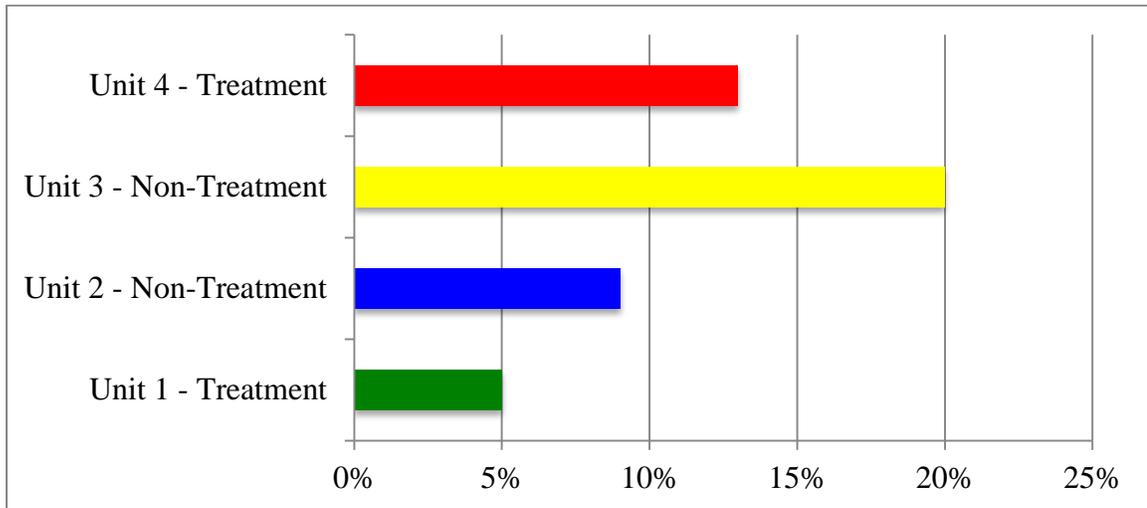


Figure 6. Missing assignments per unit, (N=26).

When reflecting in their notebooks about which labs they enjoyed and learned the most from, the traditional Biochemistry Food Tests lab ranked high for both enjoyment and understanding, but most students were confused about what was happening during the traditional Enzyme lab. The Planarian Regeneration lab, as part of the treatment unit on Cell Reproduction was the most popular lab, with students making a clear connection in their notebook reflections between their observations and mitosis.

Data indicated that students learned the course material in all treatment and non-treatment units; however, the average class grade on the post-test was higher for the two treatment units at 85% for the Nature of Biology and 78% for Cell Reproduction, compared to 68% for Biochemistry and 69% for Cell Structure and Function (Figure 7).

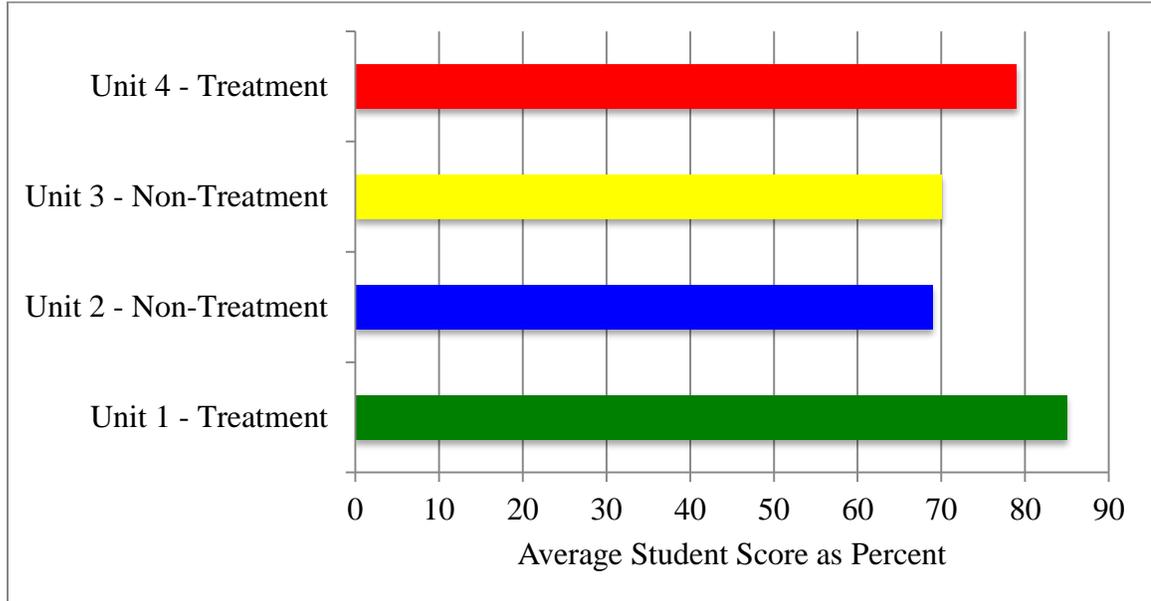


Figure 7. Average score on post-test ($N=26$).

Another teacher observation on student motivation was the reduction in student complaints after tests. In previous years following a test, students would complain about how hard science is or that they didn't do as well as they wanted to, blaming their scores on the questions being too hard. This year was the first year a pre-test was always administered, and the first year with no complaints. Student pre-test scores remained visible throughout the unit in my electronic gradebook, but were not calculated into student final grades.

INTERPRETATION AND CONCLUSION

I am very pleased with most of my findings with this study. Many previous studies indicated students learn best using inquiry based methods (Llewellyn, 2012; Trowbridge et al. 2000; Luckie et al. 2012; Lord & Orkwiszewski, 2006; NGSS Lead States, 2013) and that inquiry can be a positive motivation in the classroom (Crawford, 2000; MacIver et al., 2001; Lord & Orkwiszewski, 2006). My students improved their

MCA scores significantly while enjoying learning science. I was however, disappointed not to have seen more of a difference in content knowledge acquisition, as my results suggested that my students learned biology content equally well regardless of the instructional strategy I used.

Pre-test scores and the eighth grade Minnesota state exam (MCA) scores, indicated that this group of students was starting from an average low level of knowledge, suggesting that science might be a subject they had struggled with in the past. I was especially pleased with the gain shown on the MCA test for some of the lowest scoring students, one of whom moved from a score of 36, *does not meet*, to a score of 48, *partially meets*, only 2 points off *meeting standards*. Approximately half of this test is based around scientific practices; a topic at the core of inquiry teaching methods. I believe the significant improvements shown by students reflect the knowledge and skills in scientific practices that inquiry-teaching methods have provided them. As such, inquiry is a valuable tool in my classroom for increasing state test scores.

The higher post-test scores for both inquiry units also indicated that students had an overall greater understanding of the material when taught through inquiry activities, even though it was not significantly different from the traditional units. I think the lack of differences in normalized gain (Hake, 1998) may be influenced by other factors including students being more used to, and therefore more comfortable with traditional teaching methods. As noted by Lord and Orkwiszewski (2006) and Tweed (2009) too many students sit passively in the classroom, memorizing but not understanding content. By 10th grade many of my students have strong opinions about their preferred learning style

and want to learn in those familiar routines as indicated by their pre- and post-learning style survey question answers. Differences between the two treatment units probably reflects student familiarity with the topic, as the high average pre-test score for the Nature of Biology indicates that students had retained knowledge from previous science classes on the scientific process. Students' growing comfort and confidence with inquiry style teaching is reflected in the improvement from the first to the second treatment unit; something they were unfamiliar with prior to these lessons. High gains also reflect the low starting point for a topic, where any knowledge gained is a big improvement.

This study reflects the many disruptions and distractions that students deal with on a daily basis. During the non-treatment unit of Cell Structure and Function there was a large number of missing assignments. I believe that if students are not doing the practice work they will struggle to understand the material. During this 12-day unit we had three separate snow days, and various major sporting activities. Most of my students are actively involved in extracurricular activities, having sports practice every day for several hours. This limits their time to complete work or study for a test.

Another factor I have to take into consideration is the students who join our school in ninth grade from a parochial school that doesn't teach any science. These students have a steep learning curve compared to my other students who have had science in elementary and middle school, and specifically Life Science class during seventh grade. Based on my observations during this study, I believe that the interruptions and disruptions, a lack of prior knowledge and students' busy schedules, influenced achievement of biology content as much as the instructional strategy used.

Even though inquiry teaching strategies did not significantly alter student understanding of biology content knowledge, I found that inquiry class work could be a motivator for many students as suggested by Crawford (2000), MacIver et al., (2001), and Lord & Orkwiszewski (2006). Inquiry helped keep students focused, and increased their enjoyment of science. For one student who did not complete or turn in assignments regularly for any class, the inquiry assignments were the only ones turned in during biology class. Reflections indicated that the student enjoyed these activities, especially the Planarian Regeneration inquiry activity. The only things received from a different student however, were the traditional textbook work, a familiar teaching strategy.

When it came to enjoyment and participation, my observations and student journal reflections indicated a difference in students' attitude during class with different types of lab activities. My observations showed all students actively engaged and fully participating during the treatment-inquiry based activities. During more traditional labs there were always some students off-task; socializing with friends or playing on their iPads. Typically it was the same students each time. When re-directed, those students would get to work, but within a short time they would be off task again. From these observations I concluded that students found inquiry activities more engaging and relevant.

Traditional labs involved spending a lot of my time instructing and monitoring students to keep them working. During inquiry units when students became stuck or unsure, they were much more willing to try to find their own solution before seeking out help from each other or from me. During inquiry labs, in my role as a facilitator, rather

than constantly correcting students or keeping them on track and on time with the activity, I was able to visit with them and discuss what they were discovering. I could help them make observations and discoveries. I also found that it was during this time that I got to know my students better and made more connections with their interests, helping to make the work more relevant.

The main negative I found with using inquiry teaching strategies in my classroom was with absent students. When students were sick or took a family vacation, it was very hard to assign make-up work during the inquiry units compared to more traditional teaching methods. Students expressed their concern during those times about getting behind, and worry about misunderstanding material.

VALUE

This project has impacted me in many ways as a teacher by allowing me to modify my teaching style to increase student motivation and enjoyment of biology. It has also shown me a better way to reach struggling students and help them achieve. It has shown me that although students may struggle with inquiry, their classroom grades are unaffected, their enjoyment and motivation are improved, and the state standardized test scores are greatly improved, especially amongst the lowest achieving students. This is true with the opportunity to complete a project of their own choosing.

The findings of this study can only be of benefit when it comes to classroom management and recruiting students to take more advanced elective classes, as students are more likely to stay in science fields if they find the subject interesting and engaging. I will continue to increase the amount of inquiry that I incorporate into my classes, while

maintaining a diversity of teaching methods to address all learning styles. In particular I will increase the amount of inquiry taught to classes with traditionally lower achieving students. I will continue to have students undertake an independent inquiry project of their own choosing as I particularly appreciated the opportunities to interact with students as a facilitator during this time, helping them to find the answers and make their own discoveries. Working with students on individual inquiry projects gave me a better opportunity as a teacher to get to know my students. I am more aware of what extra-curricular activities students do, and their career aspirations, as projects would typically be centered on those themes. With this knowledge I was able to provide more relevant examples during instruction to keep students engaged and focused. Anything that improves my connection to and understanding of my students, making them realize I want to get to know them as individuals, is a benefit to classroom management.

The feedback and insight into student understanding through the use of notebook reflections has increased my ability to address students' misconceptions and, as a formative assessment tool, has proved valuable for being able to modify and adjust my day-to-day teaching. It has also given me more insight into my students' interests, as well as which activities they felt helped them to learn. Notebooking also gave students the chance to take more control of their own learning, making them think about what a lab was teaching rather than just participating for fun. I enjoyed reading student notebook entries as it gave me new insight into what students did and did not understand. It also allowed me the opportunity to provide some individual feedback to students on how to improve their learning. The biggest struggle I had with the notebook reflections was

timing; providing feedback in a timely manner that students could actually utilize in upcoming assessments. I would like to continue to use notebook reflections with my students but I need to find a more effective way of checking on them. I considered using digital notebooks for this task, but there is a strong preference with my students for handwriting compared with typing, although we are a 1:1 iPad school. I think students are more reflective and thoughtful when they have to write in a paper notebook. The time taken to read and effectively provide feedback in a timely manner will continue to be a problem, but one to which I will continue to look for a solution.

To improve my data I would have liked to increase the number of units studied. I would have liked to collect data on more than one class, but this wasn't possible as I only taught one section of 10th grade biology during the time of this study. I decided not to collect data from my advanced biology class, as the data would be very skewed, due to only three students enrolled. I will continue to analyze test data on future units as I look for ways to incorporate more inquiry.

Trying to reach all students in such a diverse group of abilities was one of the major challenges in this study. Based on my data, my principal has agreed to try splitting biology students into different levels next school year. I will be teaching two sections of Biology I, one section of which will be made up of the advanced math students only which will make differentiation easier, and an Applied Biology course to reach struggling students. This will be a less academic curriculum at a slower pace, with a lot of inquiry so that they can also achieve success.

Working on this project has made me more aware of how I teach and how students learn. It has shown me the importance of systematic data collection and analysis. This project has motivated me to look at the impact of switching to standards based grading, as I need a better way of measuring academic achievement when utilizing inquiry teaching and note booking in future years.

REFERENCES CITED

- American Association for the Advancement of Science. (1993). *Benchmark for science literacy*. Oxford: Oxford University Press. Retrieved from:
<http://www.project2061.org/publications/bsl/online/index.php>
- Bencze, J. & Bowen , G. (2009). A national science fair: Exhibiting support for the knowledge economy. *International Journal of Science Education*, 31(18), 2459-2483.
- Beermann, N. & Limberg, T. (2015) An investigation of regeneration using an invertebrate model organism: educational curriculum for high school students. Retrieved from <http://www.regenmedintheclassroom.com/>
- Booth, G. (2001). Is inquiry the answer? *The Science Teacher*, 68(7), 57-59.
- Biological Sciences Curriculum Study. (2006). *Why does science matter? Because that's what science is all about!* Colorado Springs: Kendall / Hunt Publishing Company. Retrieved February 25, 2016, from
http://bscs.org/sites/default/files/_legacy/pdf/estore_Why%20Does%20Inquiry%20Matter.pdf
- Caledonia Public Schools (2016). Retrieved March 5, 2016 from
<http://www.cps.k12.mn.us/>
- Crawford, B. A. (2000). Embracing the essence of inquiry: new roles for science teachers. *Journal of Research in Science Teaching*, 37(9), 916-937.
- Colburn, A. (2008). The prepared practitioner: Making inquiry successful. *The Science Teacher*, 75, 12.
- Council, N.R. (2000). *Inquiry and the national science education standards. A guide for teaching and learning*. Washington, D.C.: National Academy Press.
- Council, N.R. (1996). *National science education standards*. Washington, D.C.: National Academy Press.
- Fay, M. E. & Bretz, S. L. (2008). Structuring the level of inquiry in your classroom. *The Science Teacher*. 38-42
- Harmon, A. (2011, February 4). It may be a sputnik moment, but science fair are lagging. *The New York Times*. Retrieved February 20, 2016, from
http://www.nytimes.com/2011/02/05/us/05science.html?_r=0

- Hake, R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 64(1), 64-74. Retrieved October 9, 2016, from <http://dx.doi.org/10.1119/1.18809>
- Hung, M. (2010). What matters in inquiry-based science instruction? *ERIC Digest*. Retrieved February 15, 2016, from <http://files.eric.ed.gov/fulltext/ED514026.pdf>
- Kremer, K., Specht, C., Urhahne, D., & Mayer, J. (2014). The relationship in biology between the nature of science and scientific inquiry. *Journal of Biological Education*, 48, 1-8.
- Lawson, A.E. (2000). Managing the inquiry classroom: Problems and solutions. *The American Biology Teacher*, 62, 641-648.
- Llewellyn, D.J. (2012). *Teaching high school science through inquiry and argumentation*. Thousand Oaks: Corwin.
- Lord, T. & Orkwiszewski, T. (2006). Moving from didactic to inquiry-based instruction in a science laboratory. *American Biology Teacher*, 68, 342-345.
- Luckie, D., Aubry, J., Marengo, B., Rivkin, A., Foos, L., & Maleszewski, J. (2012). Less teaching, more learning: 10 year study supports increasing student learning through less coverage and more inquiry. *Advances in Physiology Education*, 36, 325-335.
- Mascarelli, A. (2011, October 5). Science fairs: Teaching students to think like scientists [Web log post]. Retrieved February 20, 2016 from <https://student.societyforscience.org/article/science-fairs-teaching-students-think-scientists>
- McDonald, G., (2012). Teaching critical & analytical thinking in high school biology? *The American Biology Teacher*, 74, 178-181.
- MacIver, D. J., Young, E. M., & Washburn, B. (2001). Instructional practices and motivation during middle school (with special attention to science). Retrieved February 15, 2016, from <http://files.eric.ed.gov/fulltext/ED452072.pdf>
- NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States*. Washington, DC: National Academies Press.
- NSTA Board of Directors. (2004). *Position statement on scientific inquiry*. Retrieved February 13, 2016, from http://www.nsta.org/docs/PositionStatement_ScientificInquiry.pdf

- Noddings, N. (2008). All our students thinking. *Educational Leadership*, 65, 8-13.
- Peters, E. (2005). Reforming cookbook labs. *Science scope*, 29, 16-21
- Project Neuron (2012). *What can I learn from worms?* Retrieved from <https://neuron.illinois.edu/units/what-can-i-learn-from-worms>
- Roehrig, G., & Luft, J. (2007). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *Journal of Science Education*, 26, 3-24.
- Sampson, V., Enderle, P., Gleim, L., Grooms, J., Hester, M., Southerland, S., and Wilson, K. (2014). *Argument-driven inquiry in biology: Lab investigations for grades 9-12*. Arlington, VA. NSTA Press.
- Shields, M. (2006). *Biology Inquiries: Standards-based labs, assessments, and discussion lessons*. San Francisco, CA. Jossey-Bass.
- Shymansky, J., Wang, T., Annetta, L., Yore., Everett, S. (2013). The impact of a multi year, multi-school district K-6 professional development programme designed to integrate science inquiry and language arts on students' high stakes test scores. *International Journal of Science Education*, 35, 956-979.
- Timmerman, B., Strickland, D., Carstensen, S. (2008). Curricular reform and inquiry teaching in biology: where are our efforts most fruitfully invested? *Integrative and Comparative Biology*, 48, 226-240.
- Trowbridge, L.W., Bybee, R.W. & Powell, J.C. (2000). *Teaching secondary school science: Strategies for developing scientific literacy*. Upper Saddle River. Merrill Prentice Hall.
- Tweed, A. (2009). *Designing effective science instruction; What works in science classrooms*. Arlington: NSTA Press.

APPENDICIES

APPENDIX A
IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
 c/o Microbiology & Immunology
 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
 FAX: 406-994-4303
 E-mail: cherylj@montana.edu

Chair: Mark Quinn
 406-994-4707
 mquinn@montana.edu
Administrator:
 Cheryl Johnson
 406-994-4706
 cherylj@montana.edu

MEMORANDUM

TO: Zoe Lamm and John Graves
FROM: Mark Quinn *Mark Quinn*
DATE: October 10, 2016
SUBJECT: "Do Inquiry Based Teaching Practices Improve Scientific Literacy and Student Motivation?" [ZL101016-EX]

The above research, described in your submission of **October 10, 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:

- (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.
- (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
SURVEY OF SCIENCE RELATED ATTITUDES

Survey of Science Related Attitudes

Participation in this survey is voluntary and participation or non-participation will not affect your grades or class standing in any way.

For each question mark only one number.

1. I learn best when labs are highly structured, where every step is outlined for me.
Strongly Disagree 1 2 3 4 Strongly Agree
2. I think science lessons are fun.
Strongly Disagree 1 2 3 4 Strongly Agree
3. Science is one of my most interesting classes
Strongly Disagree 1 2 3 4 Strongly Agree
4. I would prefer to do an experiment on a topic than to read about it.
Strongly Disagree 1 2 3 4 Strongly Agree
5. I would rather just use other people's results than do an experiment to find out my own results.
Strongly Agree 1 2 3 4 Strongly Disagree
6. I dislike science lessons
Strongly Agree 1 2 3 4 Strongly Disagree
7. School would be improved if there were no more science classes.
Strongly Agree 1 2 3 4 Strongly Disagree
8. I learn science best when I design my own labs
Strongly Disagree 1 2 3 4 Strongly Agree
9. I prefer to find the answer to a question by doing an experiment, rather than asking a friend for the answer.
Strongly Disagree 1 2 3 4 Strongly Agree
10. I prefer to do an experiment to learn a topic, than listen to a teacher explain the topic.
Strongly Disagree 1 2 3 4 Strongly Agree
11. Doing experiments doesn't give as clear information as being told the information by your teacher.
Strongly Agree 1 2 3 4 Strongly Disagree

12. I learn science best by doing labs.
Strongly Disagree 1 2 3 4 Strongly Agree
13. I come away from a lab knowing and understanding the reason for the lab.
Strongly Disagree 1 2 3 4 Strongly Agree
14. It is better to just ask the teacher for the answer than to try and find it out by experiments.
Strongly Agree 1 2 3 4 Strongly Disagree
15. I prefer to do an experiment than to watch a Youtube video to get information.
Strongly Disagree 1 2 3 4 Strongly Agree
16. I expect to do well in biology class.
Strongly Disagree 1 2 3 4 Strongly Agree
17. I prefer to discover why something happens by experimenting rather than by being told.
Strongly Disagree 1 2 3 4 Strongly Agree
18. The material taught in science class is uninteresting.
Strongly Agree 1 2 3 4 Strongly Disagree
19. I would rather ask an expert, than do an experiment to find the answer myself.
Strongly Agree 1 2 3 4 Strongly Disagree
20. School should have more science classes available.
Strongly Disagree 1 2 3 4 Strongly Agree
21. I enjoy going to science class.
Strongly Disagree 1 2 3 4 Strongly Agree
22. Doing labs is fun for me.
Strongly Disagree 1 2 3 4 Strongly Agree
23. I prefer to do a lab, instead of the teacher telling me the answer.
Strongly Disagree 1 2 3 4 Strongly Agree
24. Science class is a waste of my time.
Strongly Agree 1 2 3 4 Strongly Disagree

25. Lab questions at the end of the lab help me to understand the scientific concepts of labs.

Strongly Disagree 1 2 3 4 Strongly Agree

26. I like to design my own labs.

Strongly Disagree 1 2 3 4 Strongly Agree

Short Answer Questions

1. How well do labs help you to understand biology?

2. Do you benefit from designing and carrying out your own experiment?

3. Why do teachers give labs in science class?

4. How well do you understand the purpose of the labs we do in class?

APPENDIX C
PRE/POST UNIT TESTS

Name: _____

Date: _____

Introduction to Biology Pre/Post Test

1. Which of the following is NOT a goal of science?
 - a. to investigate and understand the natural world
 - b. to explain events in the natural world
 - c. to establish a collection of unchanging truths
 - d. to use derived explanations to make useful predictions

2. The work of scientists usually begins
 - a. Testing a hypothesis
 - b. Careful observations
 - c. Creating experiments
 - d. Drawing conclusions

3. Which of the following is NOT a characteristic of all living things?
 - a. Growth and development
 - b. The ability to move
 - c. Response to the environment
 - d. Ability to reproduce

4. Which of the following characteristics of living things best explains why some North American birds fly south for the winter?
 - a. Living things respond to their environment
 - b. Living things maintain internal balance
 - c. Living things are made up of units called cells
 - d. Living things are made up of a universal genetic code

5. Science differs from other disciplines, such as history and the arts, because science relies on
 - a. Facts
 - b. Testing explanations
 - c. Observations
 - d. Theories

6. Why is creativity considered a scientific attitude?
 - a. Scientists need creativity to make good posters to explain their ideas.
 - b. Creativity helps scientists come up with different experiments.
 - c. Creative scientists imagine the results of experiments without doing them.

- d. Scientists who are creative are better at handling and training animals.

7. Figure 1-1 illustrates which characteristic of living things?

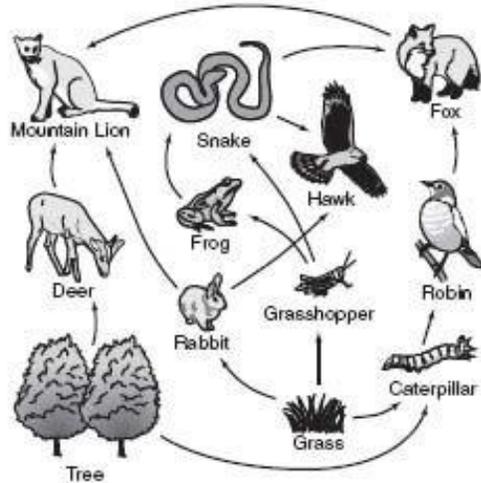


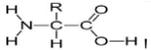
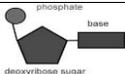
Figure 1-1

- a. Living things grow and develop
 - b. Living things are made up of cells
 - c. Living things need materials and energy
 - d. Living things reproduce
8. Plants and fungi are not living animals are living.
- a. True
 - b. False
9. Respiration means breathing, plants don't respire.
- a. True
 - b. False
10. All living things have organs.
- a. True
 - b. False
11. Growth and development are not the same
- a. True
 - b. False
12. All living things share certain characteristics.
- a. True
 - b. False

Biochemistry Pre/Post Test

- Why do cells need buffering agents?
 - to maintain constant internal environment at a pH of 10
 - to minimize the changes in pH of the internal environment
 - to function properly in an extremely basic internal environment
 - to function properly in an extremely acid internal environment
- Which of the following types of molecules has the primary function of providing a rapidly available energy source for living things?
 - Proteins
 - Carbohydrates
 - Lipids
 - Amino acids
- Which of the following types of molecules provides building blocks for tissues, transports other molecules, and helps to regulate certain reactions in the human body?
 - Lipids
 - Nucleic Acids
 - Carbohydrates
 - Proteins

Use the chart below for questions 4 and 5:

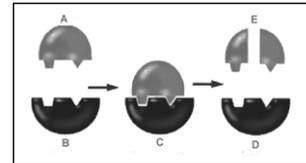
Class of substance	Basic unit of structure	One possible function	Examples
Protein		Speeds up reactions	A
Carbohydrate	B	Structural component of cell walls	C
Lipids	Glycerol and fatty acids	D	Fats, oils
Nucleic Acids		Stores and transmits heredity	DNA, RNA

- In which section of the chart do starch and glycogen belong?
 - A
 - B
 - C
 - D
- In which section of the chart does "structural component of cell membranes" belong?
 - A
 - B
 - C
 - D
- What is the function of enzymes in biological systems?
 - Enzymes act as products to create new chemical reactions.
 - Enzymes act as substrates when the necessary proteins are unavailable.
 - Enzymes act as inhibitors of chemical reactions.
 - Enzymes act as catalysts to speed up chemical reactions.
- Which of the following statements about enzymes is not true?
 - enzymes work best at a specified PH
 - enzymes increase the activation energy needed for a reaction to occur
 - enzymes are proteins
 - enzymes are organic catalysts

8. If you were conducting an experiment using an enzyme and you knew that the enzyme you were using was very sensitive to changes in pH, what would you add to your experiment to prevent the enzyme from denaturing?
- extra substrate
 - an acid
 - a base
 - a buffering agent

Use the diagram to answer questions 9 and 10:

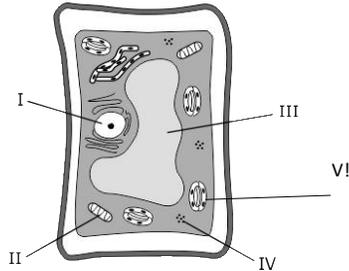
9. Which of the letters on the diagram represents the enzyme?
- A
 - B
 - C
 - D
10. Which of the letters on the diagram represents the substrate?
- A
 - B
 - C
 - D



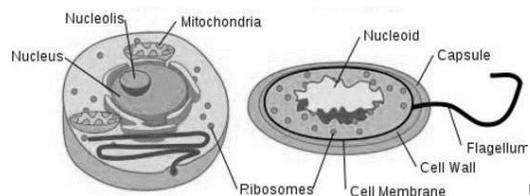
Cell Structure and Function Pre/Post Test

Name: _____

Use the diagram below to answer questions 1-4.



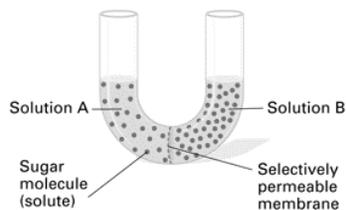
- Which structures are *most directly* involved with the synthesis of protein within the cell?
 - I and III
 - I and IV
 - II and III
 - III and IV
- How would this cell be classified?
 - As a prokaryotic plant cell
 - As a eukaryotic plant cell
 - As a prokaryotic animal cell
 - As a eukaryotic animal cell
- In which structure would starch most likely be stored?
 - I
 - II
 - III
 - IV
- Which structure is found in a plant cell but not an animal cell?
 - I
 - II
 - IV
 - V
- Some mitochondrial diseases are due to structural abnormalities within the mitochondrion itself. If a mitochondrion had a reduced number of folded membranes within it, what might be a symptom of the mitochondrial disease?
 - Increased chance of chromosomal disorders
 - Increased energy levels and hyperactivity
 - Bloating due to increased osmosis
 - Lowered energy levels and fatigue
- Which of the statements regarding prokaryotic and eukaryotic cells is true?
 - Nucleic acids are found in a nucleus in prokaryotes, but not in eukaryotes
 - Nucleic acids are present in prokaryotes, but are not present in eukaryotes
 - Nucleic acids are present in eukaryotes, but are not present in prokaryotes
 - Nucleic acids are found in a nucleus in eukaryotes, but not in prokaryotes
- Which of the cells in the diagram represents a prokaryotic cell?
 - Cell A because it has a nucleus
 - Cell A because it lacks a nucleus
 - Cell B because it has a nucleus
 - Cell B because it lacks a nucleus



- Cell A because it has a nucleus
- Cell A because it lacks a nucleus
- Cell B because it has a nucleus
- Cell B because it lacks a nucleus

8. A freshwater plant is placed in a container of saltwater. What will most likely happen to the cells of the plant?
- They will swell because water will move into them
 - They will swell because salt will move into them
 - They will shrink because water will move out of them
 - They will shrink because salt will move out of them
9. If energy is needed to move molecules into or out of the cell, what is most likely occurring?
- Active transport
 - Passive transport
 - Osmosis
 - Diffusion
10. Which would be the best evidence that a cell is using active transport to move a substance across its cell membrane?
- Substances are moving rapidly across the cell membrane
 - ATP is being rapidly consumed near the cell membrane
 - Substances are moving from high concentration to low concentration
 - Substances are moving through channels in the cell membranes

11. Which of the following describes what will happen to the solutions in the tube over time?

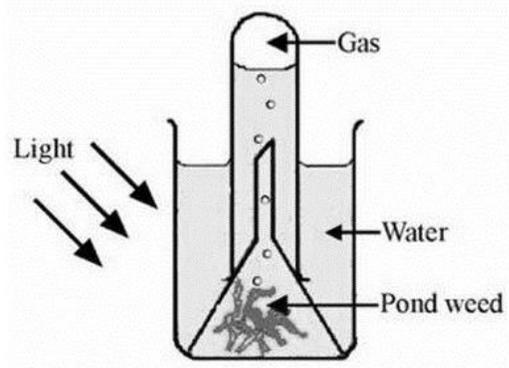


- Solution A will gain water
- Solution B will gain water
- Solution B will lose water
- Solutions A and B will not change

12. In the lungs, the movement of oxygen into cells and carbon dioxide out of cells can best be explained by which of the following processes?
- Active transport
 - Osmosis
 - Diffusion
 - Fermentation
13. What will most likely be the result if all of the mitochondria are removed from a plant cell?
- It will be unable to carry out respiration
 - It will lose water through osmosis
 - It will break down the ribosomes in the cell
 - It will be unable to photosynthesize
14. How does the amount of energy resulting from fermentation compare with that of aerobic respiration?
- Aerobic respiration results in less energy
 - Aerobic respiration results in more energy
 - Each process results in equal amounts of energy
 - Each process results in variable amounts of energy

15. In which way are photosynthesis and cellular respiration different?
- Cellular respiration stores ATP, while photosynthesis releases ATP
 - Cellular respiration produces oxygen, while photosynthesis uses oxygen
 - Photosynthesis releases energy, while cellular respiration stores energy
 - Photosynthesis produces oxygen, while cellular respiration uses oxygen

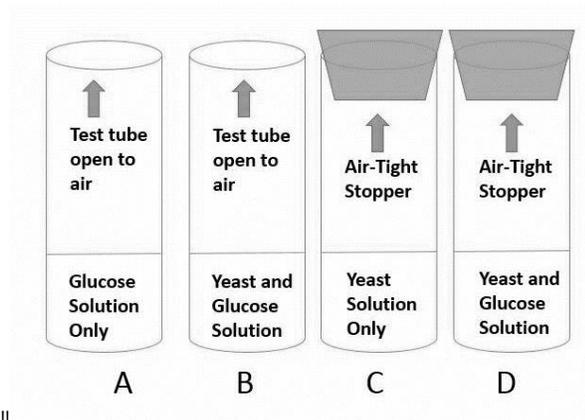
16. Based on the process illustrated in the diagram, what is being collected in the region labeled "gas"?



- Oxygen
- Carbon dioxide
- Nitrogen
- Methane

!

17. What would one expect to find in test tube "D" after several hours?



- Vinegar and lactic acid
- Glucose and oxygen
- Glucose and carbon dioxide
- Alcohol and carbon dioxide

!!!!!!

!

!

!

!

!

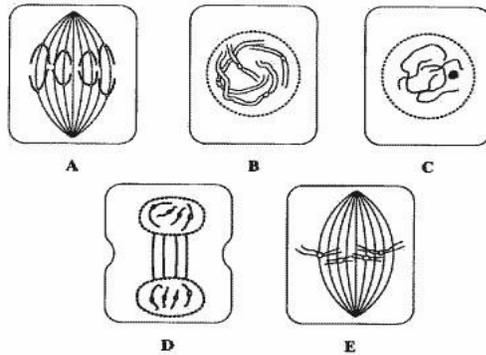
Cell Reproduction Pre/Post Test

Name: _____

1. Before mitosis begins, which happens before the nucleus starts dividing?
 - a. The cytoplasm separates
 - b. The DNA replicates
 - c. The sister chromatids separate
 - d. The homologous chromosomes separate

2. What is the result when a single cell reproduces by mitosis?
 - a. Two cells with genetic material identical to the parent
 - b. Two cells with half the genetic material of the parent cell
 - c. Four cells with half the genetic material of the parent cell
 - d. Four cells with genetic material identical to the parent cell

3. Using the diagram below, what is the correct order of cells undergoing mitosis?



- A. A - B - C - D - E
- B. C - B - D - E - A
- C. C - B - E - A - D
- D. B - C - E - A - D

4. Why is meiosis important for sexual reproduction?
 - a. It allows the zygote formed from fertilization to have triple the chromosome number of the organism
 - b. It allows the gametes to have twice the original number of chromosomes of the organism
 - c. It allows gametes to have half the original number of chromosomes of the organism
 - d. It allows the zygote formed from fertilization to have half the original number of chromosomes of the organism

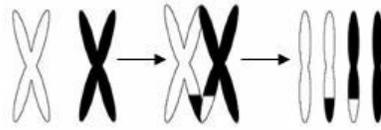
5. How are sexual and asexual reproduction different?
 - a. Sexual reproduction produces offspring identical to the parents, but asexual reproduction produces offspring with traits from both parents
 - b. Asexual reproduction produces offspring identical to the parents, but sexual reproduction produces offspring with traits from both parents
 - c. Sexual reproduction only occurs in multicellular organisms, but asexual reproduction only occurs in unicellular organisms

d. Asexual reproduction only occurs in multicellular organisms, but sexual reproduction only occurs in unicellular organisms

6. Which process produces the most genetic variation within a species?

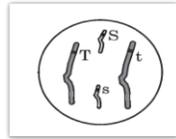
- a. Asexual reproduction
- b. Sexual reproduction
- c. Mitosis
- d. Cloning

7. Genetic variation can be obtained through the process shown below which occurs during Meiosis I. This process is called:



- A. DNA mutation
- B. Crossing Over
- C. Random fertilization
- D. Nondisjunction

8. This diagram shows a diploid cell with two pairs of homologous chromosomes. Due to independent assortment, what is the possible genetic make-up of the gametes produced by this organism?



- A. SsTt
- B. Ss, Tt
- C. S, s, T, t
- D. ST, St, sT, st

!
!

9. Plant cells that are specialized for continuous cell division are mostly found in the tips of roots and shoots. This is because...

- a. These regions have the highest rate of genetic mutation.
- b. These regions undergo the smallest amount of growth compared to other tissues.
- c. These regions undergo the greatest amount of growth compared to other tissues.
- d. These regions produce the greatest amount of protein.

!

10. The uncontrolled mitotic division of abnormal cells may result in which condition?

- a. Hemophilia
- b. Cancer
- c. Down syndrome
- d. Albinism

!

!
!
!

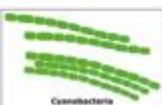
APPENDIX D:
MINNESOTA COMPREHENSIVE ASSESSMENT
(MCA) SAMPLE QUESTIONS

Section 1

Scenario: Cyanobacteria

Question 1

Cyanobacteria are aquatic bacteria with many unique characteristics. Cyanobacteria are single-celled, but sometimes they live in multicellular colonies or chains. The diagram shows cyanobacteria chains.



Genetic material in bacteria is organized differently than genetic material in plant and animal cells. Identify the correct genetic material for each cell. Drag the correct genetic material to each type of cell.

 Bacterial cell

 1 circular chromosome

 Plant cell

 Chromosomes inside a nucleus

 Animal cell

Question 2

Cyanobacteria are aquatic bacteria with many unique characteristics. Cyanobacteria are single-celled, but sometimes they live in multicellular colonies or chains. The diagram shows cyanobacteria chains.



Cyanobacteria cell membranes are selectively permeable. Cells use many methods of transport to move materials into and out of the cells. Label each method of material transport in the diagram. Drag a label into each box.

Cell membrane

Material moves against the concentration gradient, requires energy

Cell membrane

Material moves with the concentration gradient, requires proteins

Labels

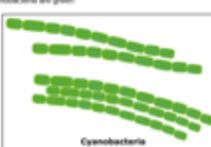
osmosis

active transport

facilitated transport

Question 3

Unlike most kinds of bacteria, cyanobacteria contain chlorophyll and perform photosynthesis. Because they contain chlorophyll, most cyanobacteria are green. The diagram shows cyanobacteria chains.



Identify 3 objects involved in photosynthesis. Drag the objects into the diagram.

 Energy Source

 Stored Energy

 Waste Product

Objects







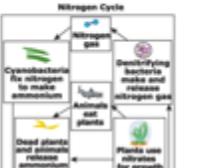






Question 4

Some cyanobacteria change nitrogen gas in the air to a usable form. These cyanobacteria are nitrogen fixers and important components of the nitrogen cycle. The diagram shows part of the nitrogen cycle in an aquatic environment.



How are cyanobacteria important to aquatic plants in the nitrogen cycle?

- A. Aquatic plants use cyanobacteria for food.
- B. Aquatic plants absorb cyanobacteria for nitrogen.
- C. Aquatic plants depend on cyanobacteria to fix nitrogen gas.
- D. Aquatic plants use the form of nitrogen made by cyanobacteria.

Question 18

This laboratory investigates bean plant growth. Select the type of soil, amount of light, and concentration of fertilizer for the trial. Select "Start" to view the resulting height of the plants.

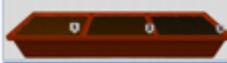
Soil	Light	Fertilizer	Result
<input type="radio"/> 50% A	<input type="radio"/> 5 hours	<input type="radio"/> 20% N	
<input type="radio"/> 50% B	<input type="radio"/> 10 hours	<input type="radio"/> 20% L	
<input type="radio"/> 50% C	<input type="radio"/> 10 hours	<input type="radio"/> 40% L	

Which statement can be defended because of the results of the investigation?

- A. The type of soil affects plant height.
- B. The amount of light has no effect on plant height.
- C. The amount of water affects the heights of the plants.
- D. The plants grow the tallest after receiving 8 mL/L of fertilizer.

Question 19

This laboratory investigates bean plant growth. Select the type of soil, amount of light, and concentration of fertilizer for the trial. Select "Start" to view the resulting height of the plants.

Soil	Light	Fertilizer	Result
<input type="radio"/> 50% A	<input type="radio"/> 5 hours	<input type="radio"/> 20% L	
<input type="radio"/> 50% B	<input type="radio"/> 10 hours	<input type="radio"/> 20% L	
<input type="radio"/> 50% C	<input type="radio"/> 10 hours	<input type="radio"/> 40% L	

Proper safety precautions should be followed when conducting scientific investigations. Identify 2 safety procedures to use in this plant growth investigation in a laboratory. Select the 2 safety precautions you want to choose.

- Use protective eyewear when handling chemical fertilizer.
- Use caution when calculating mean plant heights.
- Use gloves when applying fertilizer to the plants.
- Use caution to avoid mixing different soil types.

Question 20

This laboratory investigation tests bean plant growth. Select the type of soil, amount of light, and concentration of fertilizer for the trial. Select "Run" to view the resulting height of the plants.

Soil	Light	Fertilizer
<input type="radio"/> Soil A	<input type="radio"/> 5 Hours	<input type="radio"/> 0% N, 1% P
<input type="radio"/> Soil B	<input type="radio"/> 10 Hours	<input type="radio"/> 2% N, 1% P
<input type="radio"/> Soil C	<input type="radio"/> 15 Hours	<input type="radio"/> 4% N, 1% P

Trial	Soil	Light	Fertilizer	Plant Height (cm)
1				
2				
3				

- An investigation is designed to test the effect of the amount of light on bean plant growth. Which part of the design would add a source of error to the investigation?
- Covering all plants in different types of soil
 - Covering all plants the same amount of water
 - Providing all plants with different amounts of light
 - Supplying all plants with the same amount of fertilizer

Question 21

This laboratory investigation tests bean plant growth. Select the type of soil, amount of light, and concentration of fertilizer for the trial. Select "Run" to view the resulting height of the plants.

Soil	Light	Fertilizer
<input type="radio"/> Soil A	<input type="radio"/> 5 Hours	<input type="radio"/> 0% N, 1% P
<input type="radio"/> Soil B	<input type="radio"/> 10 Hours	<input type="radio"/> 2% N, 1% P
<input type="radio"/> Soil C	<input type="radio"/> 15 Hours	<input type="radio"/> 4% N, 1% P

Trial	Soil	Light	Fertilizer	Plant Height (cm)
1				
2				
3				

Bean plants are grown in soil C and receive 5 hours of light. Calculate the expected mean height of the plants if they receive fertilizer at a concentration of 1% N, 1% P. You can use the calculator to help you answer this question. Enter your answer in the box.

cm

Question 22

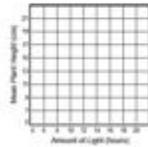
This laboratory investigation tests bean plant growth. Select the type of soil, amount of light, and concentration of fertilizer for the trial. Select "Run" to view the resulting height of the plants.

Soil	Light	Fertilizer
<input type="radio"/> Soil A	<input type="radio"/> 5 Hours	<input type="radio"/> 0% N, 1% P
<input type="radio"/> Soil B	<input type="radio"/> 10 Hours	<input type="radio"/> 2% N, 1% P
<input type="radio"/> Soil C	<input type="radio"/> 15 Hours	<input type="radio"/> 4% N, 1% P

Trial	Soil	Light	Fertilizer	Plant Height (cm)
1				
2				
3				

Use soil B and a fertilizer concentration of 4% N, 1% P to run the simulation for 5, 10, and 15 hours of light. Plot the mean plant height of plants across three 20-hour trials of light. Graph the data for 5, 10, 15, and 20 hours of light. Select the location on the graph to plot each point.

Effect of the Amount of Light on Mean Plant Height



Question 23

This laboratory investigation tests bean plant growth. Select the type of soil, amount of light, and concentration of fertilizer for the trial. Select "Run" to view the resulting height of the plants.

Soil	Light	Fertilizer
<input type="radio"/> Soil A	<input type="radio"/> 5 Hours	<input type="radio"/> 0% N, 1% P
<input type="radio"/> Soil B	<input type="radio"/> 10 Hours	<input type="radio"/> 2% N, 1% P
<input type="radio"/> Soil C	<input type="radio"/> 15 Hours	<input type="radio"/> 4% N, 1% P

Trial	Soil	Light	Fertilizer	Plant Height (cm)
1				
2				
3				

Conduct an investigation to test the hypothesis that bean plant growth is affected by the amount of light. After you conduct the investigation, go on to the next question.

APPENDIX E:
POST LAB NOTEBOOK REFLECTION QUESTIONS

Post-Lab Reflection Questions:

Write a paragraph to reflect upon what you have just learned in this lab, and how it helped you to learn our current biology topic. Ideas to include in your reflection:

- What did you learn by doing this lab / activity?
- How does this lab relate to *(fill in topic currently being studied)*?
- What did you struggle with?
- What are you still unclear about?
- What else would you like to learn about the topic?
- What will you need to study before the unit test?

APPENDIX F:
STUDENT ENGAGEMENT OBSERVATION
AND QUESTION FORM

Student Engagement Observation and Question Form

Student Name:

Date/Time:

Group Members:

Number of Students in Group: 1 2 3 4 5

Level of engagement: *outwardly negative* (1) *disinterested* (2) *passive/neutral* (3)
moderate enthusiasm (4) *excited* (5)

Behavior Observed:

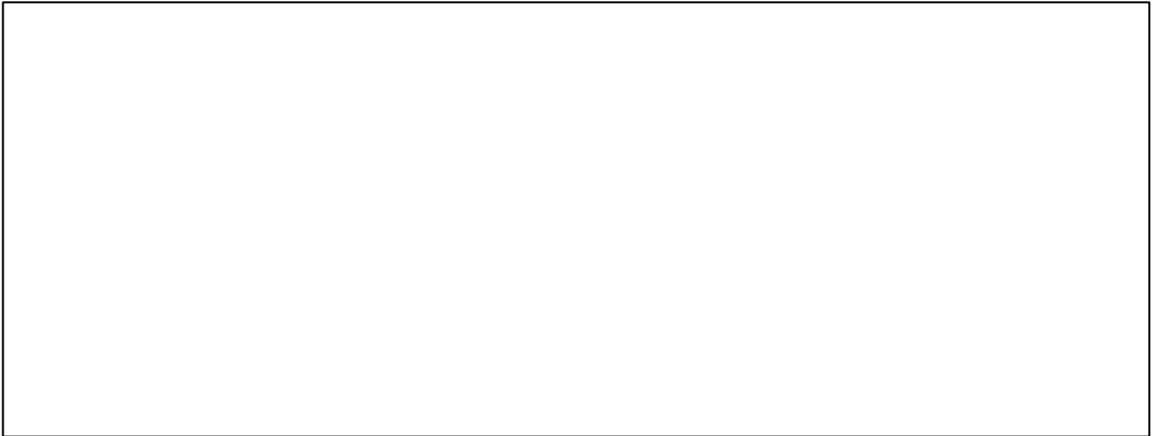
On-Task	Listening/watching	Off-Task	Passive
	Writing		Doing work for another class
	Speaking / instructing		Talking / listening to other students
	Reading		Disturbing others
	Doing lab / hands-on activity		Playing

Other Observations:

Possible question prompts:

- What part are you struggling on? What don't you understand?
- Do you understand the instructions?
- Do you understand what you should be doing at the moment?
- Why are you not participating in the activity?
- Have you asked your lab partners for help?

Questions and Responses:

A large, empty rectangular box with a thin black border, intended for students to write their questions and responses. The box is currently blank.