THE IMPACT OF MANIPULATIVE MODELS ON STUDENT UNDERSTANDING OF, ENGAGEMENT IN, AND CONFIDENCE IN ABSTRACT BIOLOGICAL PROCESSES

by

Joe M. Ruffatto

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 2012

STATEMENT OF PERMISSION TO USE

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

Joe M. Ruffatto

July 2012

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The purpose of this action research project was to investigate the efficacy of the use of hands on manipulative models in order to teach abstract biochemical processes. Students utilized enactive, hands-on modeling of photosynthesis, cellular respiration, cell division, DNA replication, and protein synthesis in order to advance to symbolic understanding of these subjects. In these activities, students acted out these processes with Students were assessed in order to see if confidence, engagement and understanding were improved. When monitored by a passive observer, increases in student engagement were observed.. Students reported that they were more confident in their ability to learn science material. Students also performed better on exams and showed longitudinal retention of material from the treatment lessons.

INTRODUCTION AND BACKGROUND

This research was conducted at Great Falls High School in Great Falls, MT. Great Falls High School is one of two large public high schools in the Great Falls School District. The school serves approximately 1,400 students. Of these students, approximately 90% are Caucasian, while 5% are Native American, 2% are Hispanic or Latino and the remaining 3% are made up of various other groups (Great Falls Public Schools, 2010).

During the 2011-12 school year, I taught five periods of an introductory biology course for sophomore students. I have taught biology and physical science for four years. This course surveys the life sciences and includes major themes of ecology, cell biology, molecular biology, anatomy and physiology. My goal in teaching this class has been to give students knowledge and skills in the life sciences that will be useful in their lives and prepare them for higher level science courses. Enrollment in the class is required for graduation from Great Falls High School. Class populations are mixed to include students of all abilities.

Great Falls Public Schools have recently implemented a new science curriculum that begins in kindergarten and lasts through all high school science classes. Among the goals of this new curriculum were intentions to deliver content using high-interest, engaging pedagogical techniques and more inquiry-based instruction. As the new curriculum was implemented, several of the Great Falls introductory biology teachers were struggling to find ways to create activities and investigations that could be adapted to an inquiry style of instruction.

Personally, I have worked hard to implement inquiry-based units as much as

possible, but some areas of the class content have been more difficult to adapt to an inquiry approach. Part of my problem involved the teaching of abstract biological processes like photosynthesis and protein synthesis that I found difficult to represent concretely. This research project sought to investigate effective methods for teaching these complex biological processes.

The focus of this research was to determine the effect of using manipulative models to teach abstract biological process on student learning. Sub-Questions included:

1) What effect do manipulative models have on students' ability to understand complex biological systems?
2) What effect does the use of manipulatives have on students' confidence?
3) What effect does the use of manipulatives have on student engagement in class?

CONCEPTUAL FRAMEWORK

In the science classroom, instructional approaches often neglect achievement of higher order comprehension of abstract ideas like chemical reactions and protein synthesis in meaningful ways. The traditional instructional methods of many science teachers and textbooks focus on fact recall (Mintzes & Wandersee, 1998). This concentration on lower-order thinking skills deemphasizes students' ability to master complex topics and skills (Mayer, 2002).

Another issue existing in science classrooms is a lack of student engagement. Newman (1992) says this about engaged students:

Engaged students make a psychological investment in learning. They try hard to

> learn what school offers. They take pride not simply in earning the formal indicators of success (grades), but in understanding the material and incorporating and internalizing it in their lives. (p. 2)

Most high school mathematics and science classrooms do not properly hold student engagement (Uekara, Borman & Lee, 2007). Engaging students is an essential part of education. According to a 2006 national survey on high school student engagement, 28% of students self-report as being unengaged in school (Yazzie-Mintz, 2007). The survey also revealed that 73% of those considering dropping out did not like school, and 60% of possible dropouts did not find value in their school work.

One way to increase student engagement is with the use of manipulative materials during instruction. Manipulatives are concrete objects that can be investigated through touch (Eyster & Tashiro, 1997). In biology, manipulatives may include models used to represent molecules or lab specimens used in dissection. The use of manipulatives in a high school science classroom may have a beneficial impact on mastering abstract concepts and student engagement. In one study, students who used manipulative were better able to recall events than their counterparts who were not taught using manipulatives (Marley & Szabo, 2010). When high school students are taught with and without manipulatives, those taught with manipulatives perform significantly better on assessments than those taught without manipulatives (Auberime, 2007).

The use of these hands-on materials is less evident for teaching abstract science topics at the secondary level. Mathematics and early childhood instructors can justify the use of manipulatives based on Piaget's constructivist learning theory. Piaget’s theoretical work divides students into four groups based on age and cognitive development (Schunk,

2008)

- Sensorimotor Stage: In this stage young children (ages 0-2) gain understanding based on the physical actions they can perform on their surroundings
- Preoperational Stage: Children ages 2-7 are heavily perceptually oriented, but are able to reflect on the past and imagine the future. The lack the ability to think in many dimensions at once.
- Concrete Operational Stage: Children ages 7-11 begin to think abstractly. They can draw on experience to understand the world around them, but understanding is often limited to properties and actions.
- Formal Operational Stage: In this final stage of development, reasoning abilities improve and students are able to think about hypothetical circumstances. (p. 338-339)

During the concrete operational stage, students are able to conceptualize logically "only after a great deal of experience with objects has accumulated" (Phillips & Soltis, 2004, p. 43). According to the constructivist theory of learning, students eventually move to a higher developmental level, the formal operational stage, allowing them to master subject matter symbolically without manipulatives and models.

> Piaget summarized his constructivism learning theory in the following way: Actually, in order to know objects, the subject must act upon them, and therefore transform them: he must displace, correct, combine, take part, and reassemble them. From the most elementary sensorimotor actions (such as pushing and pulling) to the most sophisticated intellectual operations, which are interiorized

> actions, carried out mentally (e.g. joining together, putting in order, putting into one-to-one correspondence), knowledge is constantly linked with actions or operations, that is, with transformations. (Phillips & Soltis, 2004, p. 44)

While Piaget's constructivist learning theory emphasizes the use of manipulatives with young learners, other educational theorists did not limit the use of manipulatives to early learners. Jerome Bruner introduced three modes of knowledge representation similar to Piaget's stages of development (Schunk, 2008). However, this progression through stages is not age dependent but separate for individual disciplines. Bruner asserted that learners are able to represent knowledge in the following modes (Schunk, 2008)

- Enactive learners use an action based representation of knowledge which involves the manipulation of the environment.
- Iconic learners use an image based representation of knowledge and are able to think about objects separate from manipulation.
- Symbolic learners represent knowledge with language and symbols (p. 343)

According to this theory of learning, learners must first establish an ability to actively display their knowledge before moving on to iconic and symbolic representations. The use of hands-on models allows students to concretely explore relationships that can later be translated into symbolic form. While manipulative use can be helpful to learners of any age, the use of manipulative dwindles after early stages of cognitive development (Johnson, 2005). There is promise in using manipulatives in the upper grades according to Weiss (2006). When students are presented with new abstract

concepts in high level science and math, manipulatives can help to conceptualize these difficult ideas.

Not only can hands-on models help students build understanding of advanced ideas, they can also improve student engagement. Research into manipulative use in mathematics in the higher grades reveals that students enjoy activities with manipulatives and are more engaged (Steele, 1993). However, little research has been done on manipulatives in the context of a science classroom. While manipulatives are traditionally used in early education and mathematics to help students visualize and conceptualize abstract ideas, they may be found useful in a secondary science setting to assist students in understanding theoretical and abstract content.

The use of manipulatives and models in the classroom must be done correctly. Improper use of manipulatives can lead to students' inability to bridge the gap between the physical and symbolic world (Heddens, 1997). Another caution is that students do not have the same background knowledge as the teacher, and students may have a difficult time visualizing a model as easily as the teacher may expect (Greca & Moreira, 2000).

METHODOLOGY

For the four month treatment period, I implemented hands-on strategies for teaching biological processes that allowed students to manipulate models and associate microscopic chemical processes with physical representations. The four unit treatment period was delivered to five classes of sophomore biology students. 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.

The first concept taught was the process of photosynthesis. Students utilized manipulative objects to carry out simulations of the light-dependent reactions of photosynthesis and the light-independent reactions of photosynthesis. Instead of going through the steps of photosynthesis on a white board and having the students follow along, students used physical objects to represent substrate, enzymes and other chemicals involved in the photosynthesis pathway. Students used batteries to represent ATP, the "energy currency" of cells, toy trucks to represent NADPH, which carries high energy electrons from one cellular process to another and clay and toothpick models to represent simpler molecules like water (Figures 1 and 2). These lessons lasted for two days. Manipulatives utilized in the lessons were referred to later in the unit as reminders to the students. Similar lessons were implemented to teach the topics of glycolysis, fermentation and cellular respiration.

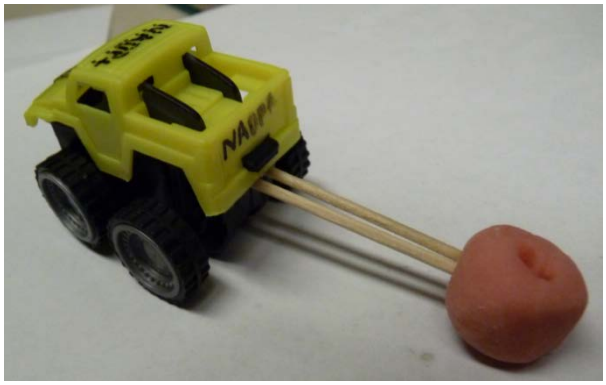

Figure 1. Student model representing NADP+ carrying hydrogen and electrons.

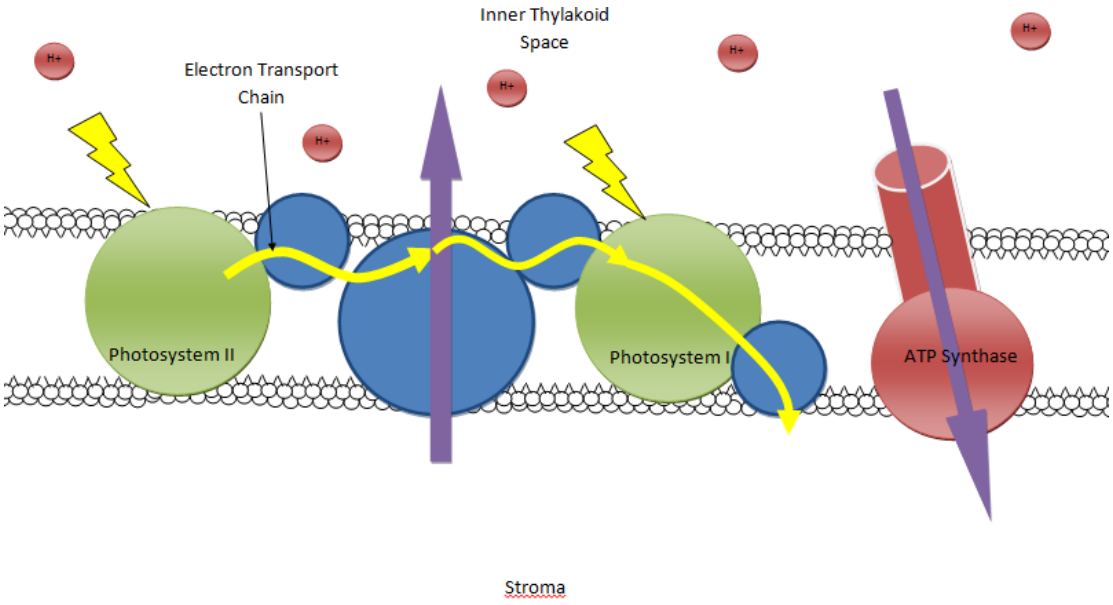

Figure 2. A large laminated version of this picture was used by students to model the process of photosynthesis with models like those pictured in Figure 1.

In the second unit, students modeled the cell cycle by using similar models. In this unit, students utilized pipe cleaners as models for chromosomes and string to represent spindle fibers. Sister chromatids were twisted together to represent the function of centromeres. Students were guided through the steps of both mitotic and meiotic cellular division and practiced representing these processes with models several times (Figure3).

Figure 3. Students using models during mitosis lesson.

The final unit of the treatment focused on the central dogma of DNA: replication, transcription and translation. Students utilized pop-beads to represent the subunits of nucleic acids and proteins and paper models to represent enzymes. Students modeled the breaking of hydrogen bonds and polymerization of complementary strands during DNA replication. Students built their own codes using a four letter language of pop beads to transmit language to their neighbors (Figure 4). After students learned that DNA could act like a code, they modeled protein synthesis and mutations with their DNA strands. In all cases, the lessons were used as springboard to elaborate on the processes further and build conceptual understanding.

Figure 4. Student model of DNA used to represent a code.

In accordance with Bruner's theory of learning, these lessons were designed to help students to transition from an inactive stage into an iconic stage of understanding. After these initial hands-on lessons, students utilized manipulatives as reference to learn about the subjects in further detail.

Prior to treatment, the Student Questionnaire was completed by a subgroup of three sophomore biology classes in order to assess student engagement and confidence in biology curriculum (Appendix B). The questionnaire was designed to investigate student confidence and engagement by comparing biology to other classes and by questioning student in their attitudes thus far in the class. Likert scale values of strongly agree (5), agree (4), neutral (3), disagree (2) and strongly disagree (1) were assigned numerical values, and the total number of students agreeing and disagreeing with statements were examined along with extended responses.

As this study was designed to measure student confidence, Quick Confidence Surveys were administered to all students prior to the treatment period (Appendix C). These surveys were developed to measure the level of student confidence before a typical non-treatment test in my course by having students quickly rate their expected grade before or after taking a test. The surveys were administered on two

occasions before the treatment period. During the first survey, two of the five class periods were assessed on their performance before taking the test, and three class periods were assessed for confidence after taking the exam. For the second pre-treatment survey period, this treatment was switched, so that pre- and post-exam data was collected for each class period. In order to assess student engagement before the treatment period, another teacher passively observed a typical class period and observed on-task and off-task student behaviors using the Passive Observer Observation Form (Appendix D). This procedure was used later during the treatment period. The percentages of students engaged in pre-treatment and treatment lessons were compared.

In order to assess student understanding of the treatment topics, students were assessed on their prior knowledge of the upcoming curriculum with Student Pre-Assessments (Appendix E). For each unit, I chose specific topics I felt were addressed by the treatment lessons. Questions about these topics were included in the pre-assessments and the students were asked about these same misconceptions in post-treatment interviews in order to see if students were able to gain understanding about the treatment topics. For the photosynthesis unit, I chose the primary source of plant biomass is from the soil instead of atmospheric carbon dioxide. I also wanted students to be able to describe the difference between mitosis and meiosis, explain the relationship between DNA and protein, and explain the molecular basis for mutations.

Following each lesson, formative assessments were used to evaluate short term gains in student understanding. Students were instructed to summarize each process using one-sentence summaries. These summaries demanded that students synthesize the information from the lesson into a single complex sentence that explains “What happens

when, where, how and why?"

Summative assessments were given five times throughout the treatment period. These Understanding Post-Tests were used to separately assess student understanding of the processes of photosynthesis, respiration, mitotic cell division, meiotic cell division and DNA (Appendix F). Before each of the tests, students completed the Quick Confidence Survey to express their confidence in the material. Students were presented with the manipulative models to utilize during the tests as a way to elicit recall for the exams. These summative assessments were identical to the summative assessments used in the class two years ago. Class averages from the 2009-2010 non-treatment classes were compared to the class averages from the treatment 2011-2012 treatment classes.

Two months following treatment, all five periods of the biology class students took the Post-Treatment Questionnaire in order to establish any changes in self-reported student engagement and confidence. In addition a group of volunteers were interviewed using the Student Interview Questions (Appendix G). These interviews included conceptual questions that were meant to address misconceptions unearthed by Student Pre-assessments. Specifically, these questions focused on topics that were introduced by the treatment lessons. Likert scale analysis from the Post-Treatment Questionnaire was compared to results from the Student Questionnaire. The Triangulation Matrix represents a summary of the tools used to assess the research questions (Table 1).

Table 1
Triangulation Matrix

Research Questions	1	2	3
Student Understanding	Student Understanding Pre-Tests	Formative Assessment – One Sentence Summaries	Student Interviews
Student Engagement	Student Questionnaire	Student Interviews	Passive Observer – Classroom Engagement Observations
Student Confidence	Student Questionnaire	Student Interviews	Quick Confidence Surveys

DATA AND ANALYSIS

The treatment group for this study consisted of 106 students. Prior to the treatment, students were surveyed for their confidence in biology material by asking them how they felt they would perform on an upcoming test with Quick Confidence Surveys (Appendix C). Of the 106 students surveyed before non-treatment exams, 7% expected to fail the test, 26% expected a D, 8% expected a C, 36% expected a B, and 23% expected an A. On another non-treatment test students were surveyed after taking their exam. When 99 of the 106 students were surveyed in the same manner, 4% felt they earned an F, 11% anticipated a D, 29% anticipated a C, 31% anticipated a B, and 24% anticipated an A.

Once treatment had begun, confidence surveys were used before and after summative assessments. Students were surveyed 297 times before summative assessments throughout the treatment period and 256 times after taking a test to assess

their confidence. When surveyed prior to tests, 4% of students indicated an expected F grade, 20% indicated a D grade, 17% indicated a C grade, 32% indicated a B grade, and 27% indicated an A grade. When surveys were taken right after students turned in their exams, but before learning their scores, 5% of surveys indicated an expected F grade, 14% indicated an expected D grade, 26% indicated an expected C grade, 30% indicated an expected B grade, and 25% indicated an expected A grade. Figure 5 and Figure 6 show the difference in Quick Confidence Survey responses when comparing the treatment and non-treatment responses.

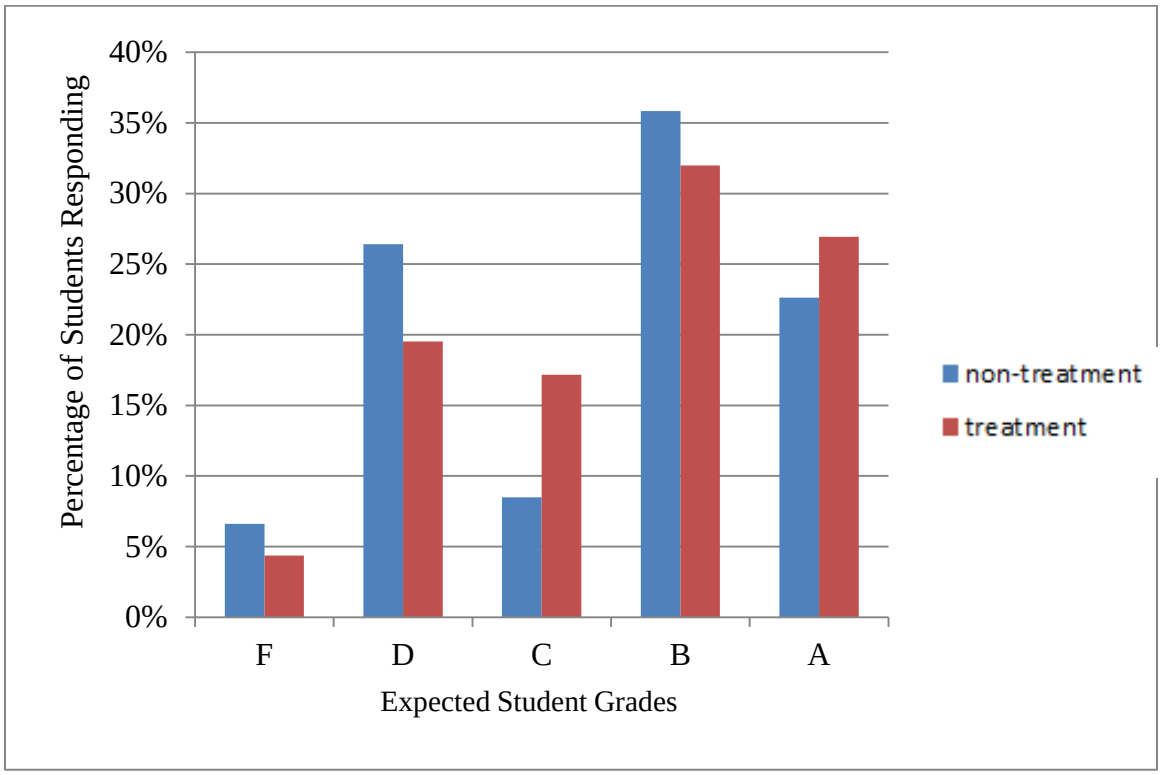

Figure 5. Percentages of students expecting A-F grades on exams when surveyed before treatment and non-treatment exams, (*N*=106).

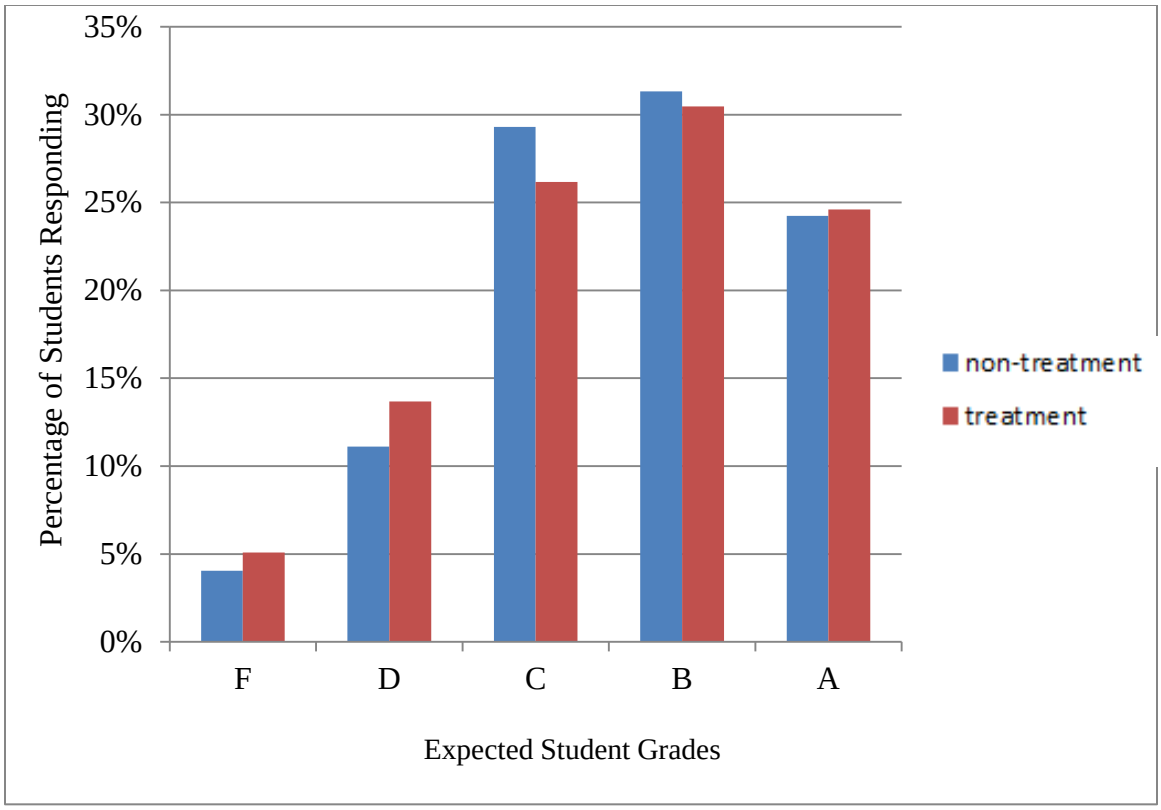

Figure 6. Percentages of students expecting A-F grades on exams when surveyed after treatment and on-treatment exams, (*N*=106).

Due to the anonymous nature of these surveys, it is impossible to precisely correlate student predictions to student scores. In all cases, the median and mode prediction for scores on the test was a B grade. These predictions were higher than test averages for three of the five summative assessments but correlated well with two of the exams.

The results of the questionnaire for confidence on a subgroup of the population indicated that 67% of students agreed that they were confident in their ability to learn science material before the treatment (*n*=55). When asked if they felt they did well on quizzes and tests, 31% agreed. Students also responded that 69% found science to be a challenging subject, 82% felt they did well during lab activities, and 51% believed they were able to assist others with biology curriculum (Figure 7).

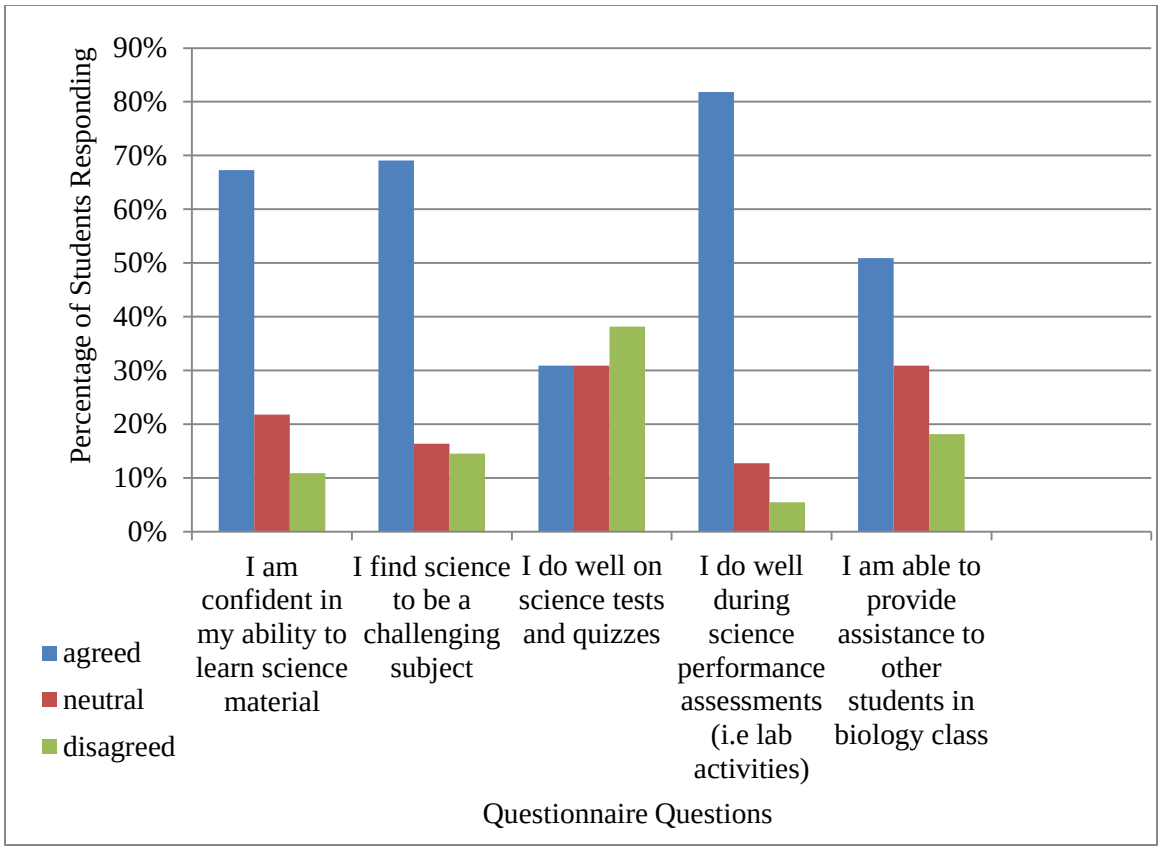

Figure 7. Student responses to Student Questionnaire relating to confidence, (*n*=55).

The same subgroup was also asked questions regarding engagement with biology coursework (Figure 8). When asked whether working with their hands kept their attention, 95% of students agreed. The same percentage agreed that hands-on activities helped them learn better than other activities. Several students backed this up with open response answers like "When we work with our hands, I learn better then." Also, when asked what could be done in class to improve your engagement, several students indicated that hands-on activities are important. One student wrote, "More hands-on labs [would help.]" Another indicated that "less lecture" would be a good way to make the class more engaging. The questionnaires also showed that 53% found biology class to be engaging. When asked whether they sometimes *zoned out* in class, 40% of students agreed. When asked whether they agreed with the statement "I find science more

interesting when I can conduct my own investigations," 35% of students agreed.

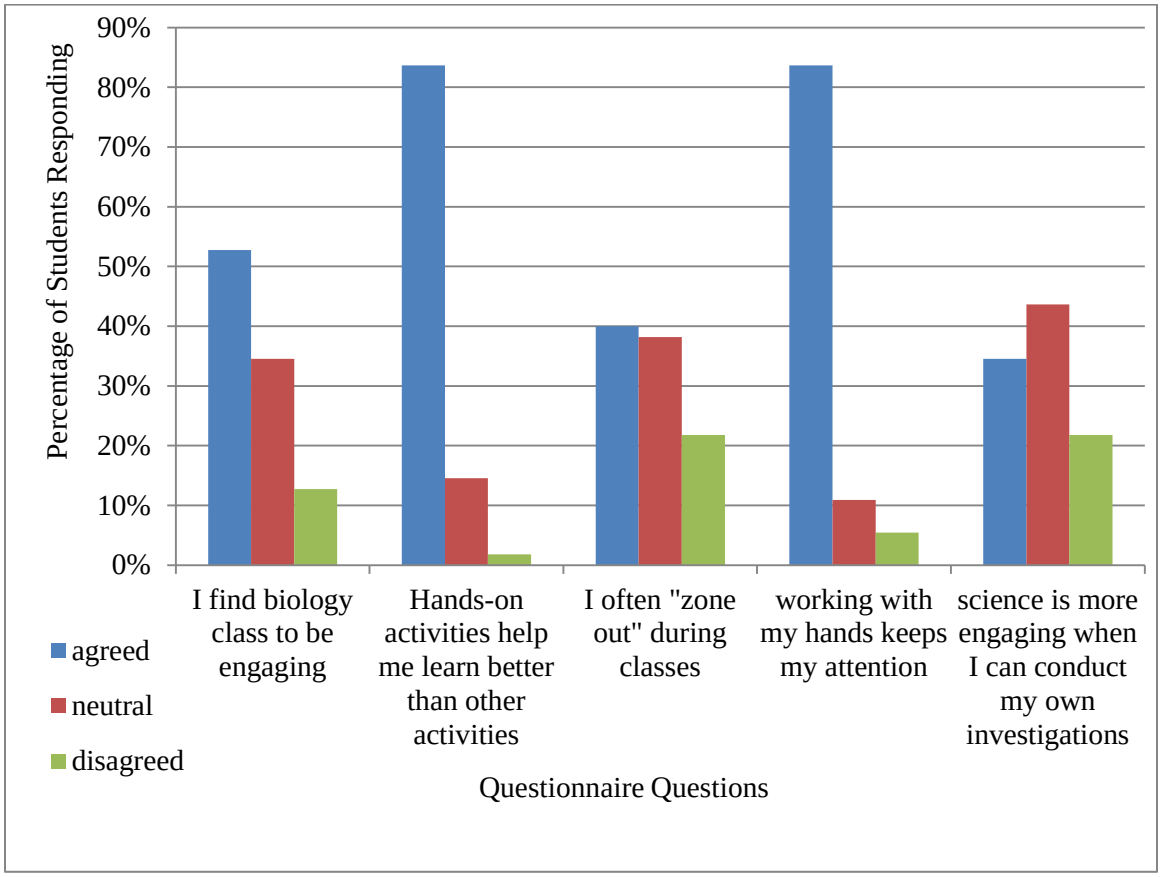

Figure 8. Student responses to Student Questionnaire relating to engagement, (*n*=55).

During both treatment, and non-treatment lessons, students were monitored by a passive teacher observer who recorded student engagement. When observed every five minutes, students in the first non-treatment group were found to be on task 96% of the time. In the second non-treatment group, students were found to be engaged 91% of the time. During the two treatment lessons, students were found to be on task 97% of the time during both lessons (Figure 9).

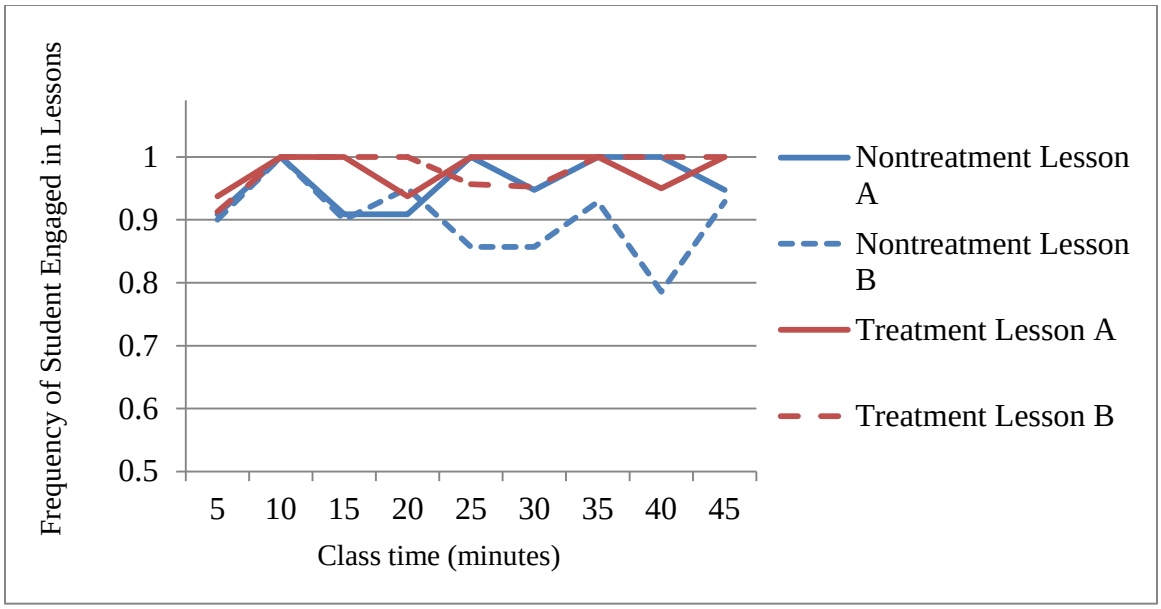

Figure 9. On task behavior for treatment and non-treatment groups.

In order to determine student understanding, a subgroup of 49 students was assessed for possible errant preconceptions using the first of three Student Pre-Assessments (Appendix E). When asked to identify the source of plants' biomass, 49% of students identified soil, 20% identified water and 12% identified sunlight. No students were aware that the largest source of a plants biomass is from atmospheric carbon dioxide. While 94% of subgroup identified plants as the source of oxygen in the atmosphere, none of them were able to point out that plants also use oxygen to carry out cellular respiration.

Another subgroup was administered the second Student Pre-Assessment dealing with cell growth and division (n=61). While 93% of students understood that mitosis had to do with cell division, no students were able to specifically define it as the process of nuclear division. No students were able to describe meiosis, the type of division required to create gametes.

Prior to the unit focusing on DNA, RNA and protein, another subgroup was

assessed with the final Student Pre-Assessment (*n*= 81). Many students, 83%, were able to establish at least a rudimentary understanding of the function of DNA as the molecule responsible for traits or genetic information. Fewer students, 23%, were able to identify that a function of DNA is to pass on information from one generation to another. There were several misconceptions about the nature of mutations, For example, 14% of students defined mutations as any birth defect or deformity. When asked about the cause of mutations, 4% identified viruses, 4% inbreeding and 16% correctly identified mistakes in DNA.

At the end of the treatment units, students were given summative assessments to measure their understanding of the content. The average scores on these exams were compared to non-treatment scores on identical summative assessment from a previous school year. In all but the mitosis unit, student scores were up from the previous non-treatment unit (Figure 8). The average on the meiosis test increased 11.3%, which was the greatest amount. The scores on the other exams increased by 6.71% for photosynthesis, 5.6% for respiration, and 1.0% for DNA, RNA, and protein (Figure 10).

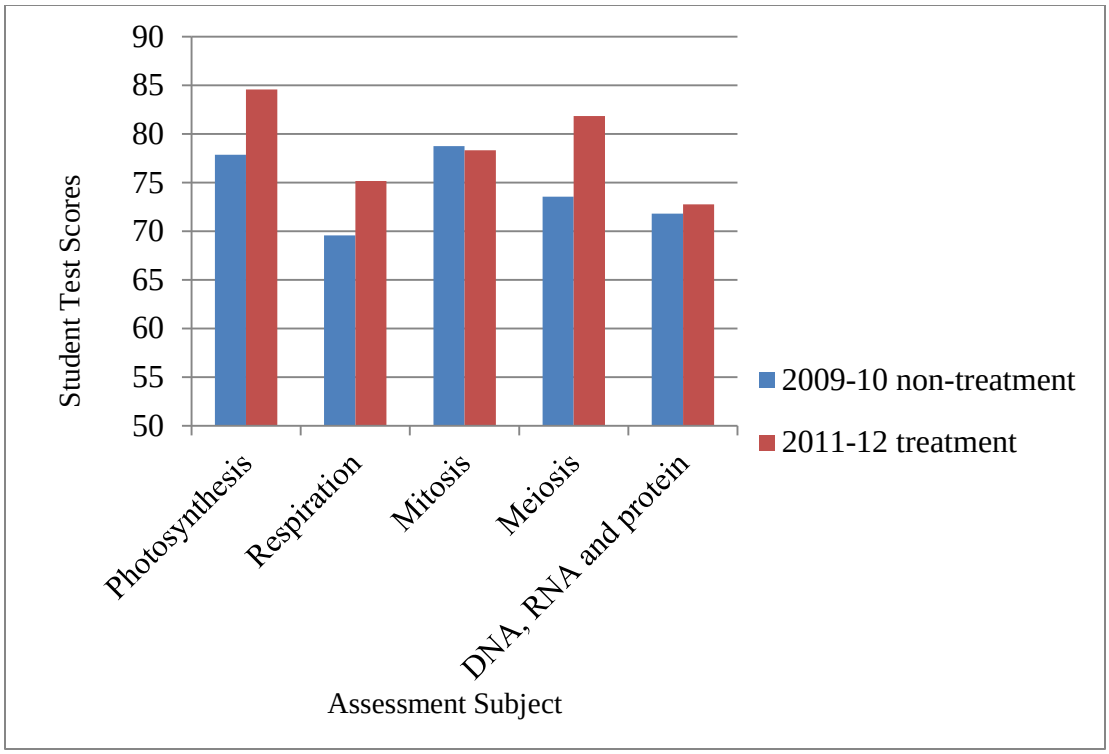

Figure 10. Average of all students' summative test scores for 2009-2010 non-treatment group compared to 2011-2012 treatment classes.

After treatment, the Student Questionnaire (Appendix B) was administered again to 41 students, and a t-test was performed to find significant changes. The percentage of students agreeing with the statement 'I find science to be a challenging subject," dropped from 69% to 34% ($p < .01$). No other changes in the original questionnaire were found to be significantly different with a confidence level greater than 95%.

The same 41 students who took the questionnaire in post-treatment were also asked about several misconceptions and topics from earlier in the year. In this interview, the number of students able to define air as the primary source of plant biomass increased from 0% earlier in the year to 32% (Figure 11). The number of students able to identify plants as carrying out cellular respiration grew from 0% to 29%. The percentage of students able to differentiate properly between mitosis and meiosis rose from 0% to12%.

While most students were able to identify DNA as the molecule of information, only seven students were able to associate its function with protein synthesis without prompting. In attempting to describe mutations, 41% of students were able to precisely describe mutations as changes to the genetic code.

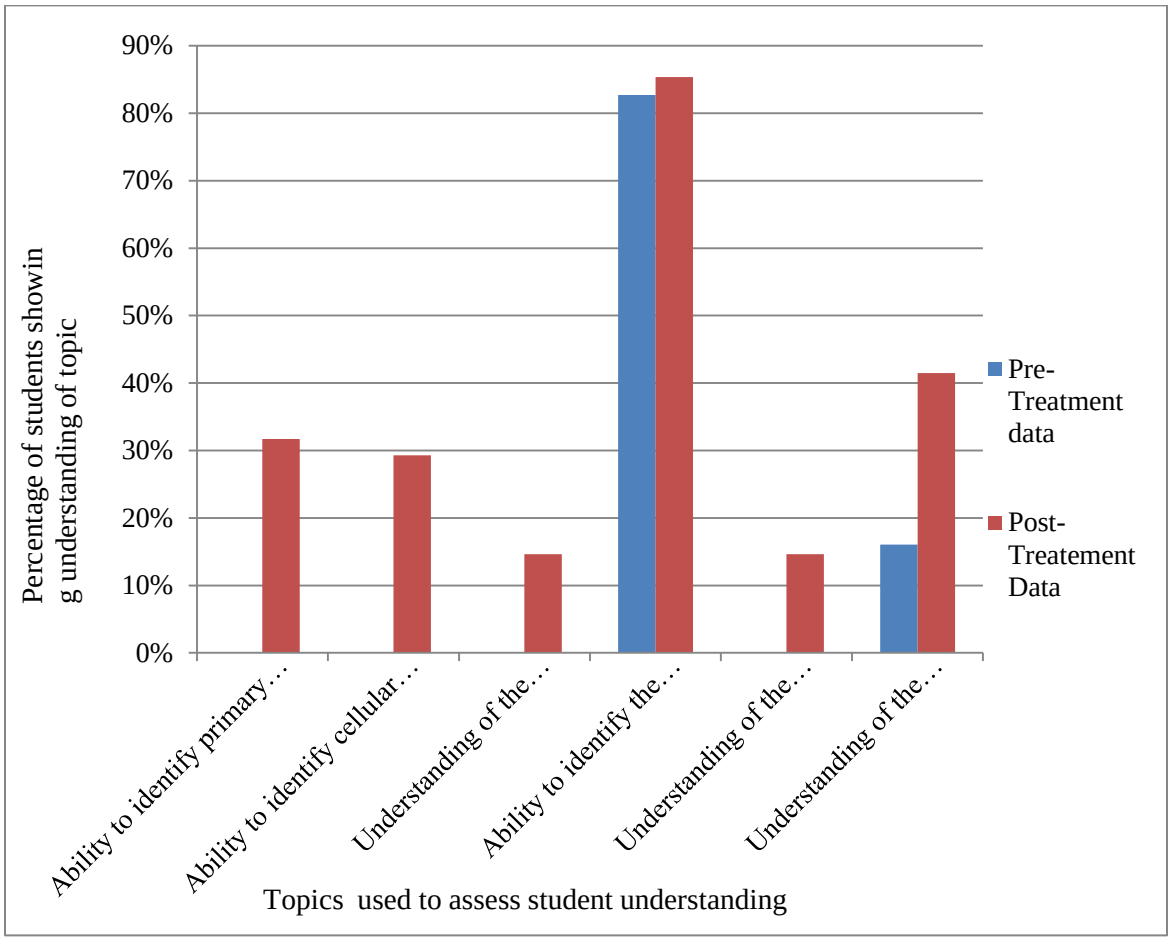

Figure 11. Student understanding of biology topics before and after treatment period.

INTERPRETATION AND CONCLUSION

Results of the study showed that when students were using hands-on methods of learning biological processes, they were more engaged than with previously used

methods like lecture and following drawings on the board. Students were more active in class according to passive observation, but students did not report significantly greater engagement according to the post-treatment questionnaire.

The study also showed some evidence that students performed well in short term assessments of knowledge. After using the hands-on methods, students were mostly able to formulize summaries of the desired content. Students also showed better scores on summative assessment when compared to the scores seen in previous years when different methods were used. When assessed longitudinally, student misconceptions decreased across the board. However, in many cases a majority of students lacked a complete understanding of the topics chosen for longitudinal assessment. Despite modeling the process of photosynthesis themselves, less than half of students could explain the role of CO_2 in plant growth. Also despite modeling the process of protein synthesis, only 17% of students were able to define DNA's relationship to protein (although, the question used to illicit this response was rather vague). The misconceptions were at lower levels, and understanding was increased, but many of the initial gains were lost. Many times, students reverted to their initial conceptions. Perhaps limited exposure to the material isn't enough to correct student misconceptions in many cases. Perhaps the lessons I utilized weren't enough to develop definitive moments of disequilibrium.

Information on student confidence was mixed. Quick Confidence Surveys before and after tests were inconclusive. No significant change in student confidence was demonstrated in comparing non-treatment Quick Confidence Surveys with treatment Quick Confidence Surveys. Students appeared to be just slightly overconfident in their

predictions when compared to actual test scores in most cases. However in looking at confidence as measured by Student Questionnaires, there was a significant increase in the number of students agreeing that they were confident in their ability to learn science material.

VALUE

The development and implementation of this capstone project has led to several changes in my professional approach. Conducting this research has exposed me to instructional approaches I previously overlooked. I am now driven to reorganize my entire curriculum to include high interest, student focused activities. Second, I am determined to use better ways to assess and improve student understanding. In particular, I am focused on seeking out student misconceptions and confronting them in an effective way in my classroom. Finally, I have a greater appreciation for the use of peer reviewed researched-based instruction and content. Whether it is encouraging students to source quality research for their papers or the use of data driven techniques in my own class, this entire experience has increased my desire to use research in my classroom.

Perhaps the most interesting part of my MSSE capstone experience was monitoring student engagement. Even after my treatment period, I took to quietly making notes at opportunities I had in class to see how many students were actively engaged in learning. After seeing the most engaging methods first hand, I am now building a curriculum that focuses on keeping students active with a learner-centered classroom. My project was an attempt to implement strands of inquiry into content that I have found difficult to approach using inquiry methods. Now, I am challenging myself to

look at every lesson of the year and think about not just how I will instruct, but how the students will become active participants.

As I worked with manipulatives as a tool for engagement, I faced a few unexpected challenges. The first time I used them in class, they were almost too engaging. Before I had a chance to explain the activity, students were playing with the manipulatives like they were toys and ignoring any learning opportunity. I was forced to punt. I collected all the manipulatives and reorganized my instructional approach and tried again the next day. The second time, I had better success in introducing the manipulatives one at a time and explaining their role in the process. I know that manipulatives will continue to be part of my classroom, but I am now looking at different approaches.

A second focus of my research was helping students achieve better understanding of difficult concepts. I found that I was successful in some ways. Students achieved good results on their summative assessments and were able to demonstrate their understanding after the treatment lessons. However I was particularly disappointed when I did longitudinal concept checks with my students. Many students showed a reversion to old misconceptions or a loss of pervious abilities. I learned throughout the MSSE program that it is very easy for students to revert to misconceptions, and I saw this frustration first hand. I now want to go further and create an approach to my teaching that allows me to assess what students already know about science and attack their misconceptions. My past implementation of assessment has focused too much on summative assessment. This has seen me frustrated when students fail to achieve to the level I expected. This failing is my own. If I can properly implement assessment of misconceptions and constant

formative assessment of students, I know my students will able to master the material, and I will see better results. The way to do this is with well researched methods.

Before my time in the MSSE program, my experience with research was something dabbled with as an undergraduate. I completed several small research projects at my time at Montana State University as an undergraduate and a referred to several research projects in the papers that I wrote. However, it was not until I was exposed to graduate level writing and research that I gained an appreciation for professional journals and how scientific knowledge is rigorously gained. In order to create a classroom that engages students and assesses them properly, my goal is to reference well researched methods in my classroom. Now, I go online to find researched methods and buy books recommended by National Science Teachers Association. I am creating and implementing lessons and units that utilize suggested methodology. After all of my reading, it is my goal to restructure my past lessons to fit suggested inquiry format.

As I come to the close of my experience with MSSE and with this school year, I have renewed spirit to create a classroom that embraces everything I've learned throughout the past few years. I want my classroom to reflect the quality methods I have learned throughout this program.

REFERENCES CITED

Auberime, F Ehi (2007). How Manipulatives Affect the Mathematics Achievement of Students in Nigerian Schools. *Educational Research Quarterly, 31(*1) 3-15

Christakis, D., Zimmerman, F., DiGiuseppe, D., & McCarty, C. (2004). Early television exposure and subsequent attentional problems in children. *Pediatrics, 113*(4), 708-713.

Eyster, L. S. and Tashiro, J. S. (1997). Using manipulatives to teach quantitative concepts in ecology. *Am. Biol. Teach*, *59*, 360–364.

Great falls public schools. (2010). Retrieved from http://www.gfps.k12.mt.us/Schools/GreatFallsHigh/GreatFallsHigh.html

Greca, I. M., & Moreira, M. A. (2000), Mental models, conceptual models, and modeling. *International Journal of Science Education, 22*(1), 1-11.

Heddens, J. W. (1997). *Improving Mathematics Teaching by Using Manipulatives.* Retrieved November 4, 2009 from Kent State University Website: http://www.fed.cuhk.edu.hk/~flee/mathfor/edumath/9706/13hedden.html .

Johnson, L. (2005). Math manipulatives. *International Children's Education.* Retrieved February 24, 2010 from http://www.iched.org/cms/scripts/page.php?site_id=iched&item_id=math_manipulatives.

Marley, Scott C., & Szabo, Zsuzsanna (2010). Improving Children's Listening Comprehension with a Manipulation Strategy. *Journal of Educational Research, 103*(4) 227-238

Mayer, R. E. (2002). Rote versus meaningful learning. *Theory Into Practice*, *41*(4), 226-232.

Mintzes, J. J. & Wandersee, J. H. (1998) Reform and innovation in science teaching: A human constructivist view. In J. J. Mintzes, J. H. Wandersee and J. D. Novak (eds) 590 R. E. WARD AND J. H. WANDERSEE *Teaching Science for Understanding: A Human Constructivist View* (San Diego, CA: Academic Press), 328–350.

Newmann, F. M. (1992). *Student engagement and achievement in american secondary schools*. New York: Teachers College Press.

Phillips, D.C., Soltis, J. (2004). *Perspectives on Learning.* New York, NY: Teachers College Press.

Ruff, H., & Lawson, K. (1990). Development of sustained, focused attention in young children during free play. *Developmental psychology*, *26*(1), 85-93.

Schunk, D. (2008). *Learning Theories: An Educational Perspective.* Upper Saddle River, NJ: Pearson Education, Inc.

Steele, D. (1993). What mathematics students can teach us about educational engagement: lessons from the middle school. American Educational Research Association [conference] Atlanta, GA. April 13, 1993

Watt, J., & Vadanovich, S. (1999). Boredom proneness and psychosocial development. *The Journal of Psychology*, *133*(3), 303-314.

Weiss, D. (2006). Keeping it real: The rationale for using manipulatives in the middle grades. *The National Council of Teachers of Mathematics, 11(5).* Retrieved February 26, 2010, from www.nctm.org.

Uekawa, k, Borman, k, & Lee, r. (2007). Student engagement in u.s. urban high school mathematics and science classrooms: findings on social organization, race, and ethnicity . *Urban Review: Issues and Ideas in Public Education, 39*(1), 1-43.

Yazzie-Mintz, E. (2007). Voices of students on engagement: a report on the 2006 high school survey of student engagement. (Center for Evaluation and Education Policy, Indiana University). Retrieved February 23, 2010, from http://www.eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED495758&ERICExtSearch_SearchType_0=no&accno=ED495758

APPENDICES

APPENDIX A

ETHICS STATEMENT

October 24, 2010

Great Falls High School
1900 2nd Avenue South
Great Falls, MT 59405

As part of my work with Montana State University, I am conducting a piece of action research into studying how I can improve student understanding, engagement, and confidence through the use of manipulative models in biology class. I would be grateful if you would give your permission and support for this project.

My data collection will consist mostly of standard classroom assessment techniques like formative assessment, quizzes and exams. However, other data will be gathered with audio recording and student photographs. I guarantee that I will observe good ethical conduct throughout the data collection, and I will secure permission to work with the parents and children to involve them in the research. I guarantee confidentiality of information and promise that not names of colleagues or children will be made public without your permission and the permission of those who wish to be named.

I promise that I will make my research report available to your scrutiny before publication, and I will make a copy available for your files.

I have enclosed two copies of this letter. Feel free to keep one of the copies for your files.

Cordially yours,

Joe M Ruffatto

I, Fred Anderson, Principal of Great Falls Public School, give my permission for Joe Ruffatto to undertake his research in his classroom.

_____

APPENDIX B

STUDENT QUESTIONARRE

Student Questionnaire

Please respond to the following items by checking the box that most closely reflects your opinion: strongly agree(SA), agree (A), undecided (U), Disagree (D), Strongly Disagree (SD)

Participation is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at anytime. Participation or non-participation will not affect the student's grade or class standing.

	SA	A	U	D	SD
1. I am confident in my ability to learn science material.					
2. I find science to be a challenging subject.					
3. I do well on science tests and quizzes.					
4. I do well during science performance assessments (i.e. labs, activities).					
5. Lab activities help me learn science content.					
6. I am able to provide assistance to other students in biology class.					
7. I find biology class to be engaging.					
8. Hands-on activities help me learn better than other activities.					
9. I often “zone out” during classes.					
10. Working with my hands keeps my attention.					
11. Science is more interesting when I can conduct my own investigations.					

12. What kind of class activities do you find engaging? Please provide examples.

13. What are the aspects of biology class that engage your learning?

14. What could be done in class to improve your engagement?

15. Is there anything else you would like me to know?

APPENDIX C

QUICK CONFIDENCE SURVEY

Student Confidence Survey:												
Please circle the grade you expect to earn on the following exam.												
F	D-	D	D+	C-	C	C+	B-	B	B+	A-	A	A+

APPENDIX D

PASSIVE OBSERVER OBSERVATION FORM

Monitoring Student Engagement

Time: _____ Date: _____ Observer: _____

Description of Class: _____ Total Number of Students _____

At the beginning of the class, set a timer for 4 minutes. Every four minutes observe the students of the classroom and record the number of students disengaged and engaged in the classroom activity. Record the number of engaged students in the + column and the number of disengaged students in the – column.

	+	--
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10		
11.		
12.		
13.		
Totals		

Before you begin coding, clarify the definitions of both engaged and unengaged. Examples might include the following for "engaged" students: following directions given by the teacher; interacting with peers when instructed; watching the teacher; following teacher writing on the board or overhead projector; reading from the appropriate text; doing independent seat work as assigned; etc.

Unengaged students might exhibit the following kinds of behaviors: talking out of turn; behaviors that infringe on classroom rules; head down on desk; talking or passing notes to another student; reading a book that has not been assigned; listening to an iPod; etc.

APPENDIX E

STUDENT PRE-ASSESSMENTS

Photosynthesis and Respiration Pre-Assessment

1. All organisms, including plants, need food to survive. Circle all of the following items which act as food for plants

-Sunlight, sugar, carbon dioxide, minerals, fertilizer, soil, water, leaves, oxygen

2. As people grow, we accumulate more biomass by eating. As plants grow, where do they get the material that their bodies are made of?

3. What is respiration? Describe how it relates to plants and animals

4. Draw a concept map that links these terms. Add as much detail as possible. Photosynthesis, Respiration, Animals, Plants, Air, Oxygen, Carbon Dioxide, Sunlight.

Cell Growth, Division, Mitosis and Meiosis Pre-Assessment:

1.As plants and animals grow, describe what is happening to the cells of those animals?

2. What happens when a cell undergoes mitosis?

3. How many copies of DNA does every human cell normally have?

4 How are traits passed on from one generation to the next?

5. Is it possible for a person to have traits that his/her parents did not have (e.g. blue eyes when both of his/her parents have brown eyes)? Why is this?

13. How is the gender of a baby determined?

DNA and Molecular Heredity Pre-Assessment

1. What is the function of DNA?

2. What are genes and how do they function?

3. What are mutations and how are they caused?

4. Tell me everything you know about DNA.

APPENDIX F

STUDENT UNDERSTANDING POST-TESTS

Chapter 8 Test - Photosynthesis

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Which of the following is an autotroph?
a. mushroom
b. dog
c. monkey
d. Tree

____ 2. Which of the following is NOT an example of a heterotroph?
a. mushroom
b. leopard
c. grass
d. human

____ 3. Energy is released from ATP when
a. a phosphate group is added.
b. adenine bonds to ribose.
c. ATP is exposed to sunlight.
d. a phosphate group is removed.

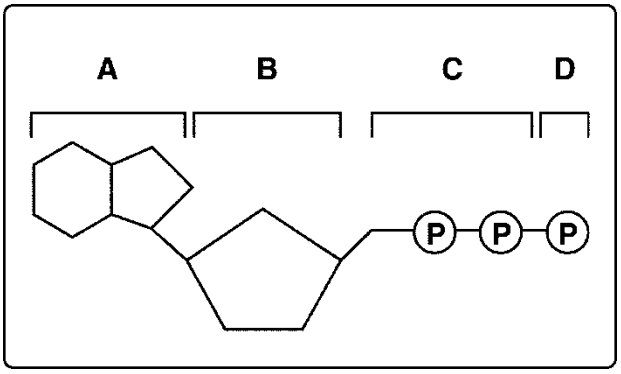

Figure 8–1

____ 4. In Figure 8-1, between which parts of the molecule must the bonds be broken to form an ADP molecule?
a. A and B
b. B and C
c. C and D
d. all of the above

____ 5. Which of the following are used in the overall reactions for photosynthesis?
a. carbon dioxide
b. water
c. light
d. all of the above

____ 6. Most plants appear green because chlorophyll
a. does not absorb green light.
b. reflects violet light.
c. absorbs green light.
d. none of the above

____ 7. The light-collecting units of a chloroplast are the
a. electron carriers.
b. photosystems.
c. stroma.
d. high-energy sugars.

____ 8. What are the products of the light-dependent reactions?
a. oxygen gas
b. ATP
c. NADPH
d. all of the above

____ 9. Which step is the beginning of photosynthesis?

a. Pigments in photosystem I absorb light.
b. Pigments in photosystem II absorb light.
c. High-energy electrons move through the electron transport chain.
d. ATP synthase allows H+ ions to pass through the thylakoid membrane.

____ 10. The Calvin cycle takes place in the
a. stroma.
b. photosystems.
c. thylakoid membranes.
d. chlorophyll molecules.

____ 11. If carbon dioxide is removed from a plant's environment, what would you expect to happen to its production of high-energy sugars?
a. More sugars will be produced.
b. No sugars will be produced.
c. The same number of sugars will be produced but without carbon dioxide.
d. Carbon dioxide does not affect the production of high-energy sugars in plants.

____ 12. Organisms, such as plants, that make their own food are called
a. autotrophs.
b. heterotrophs.
c. thylakoids.
d. pigments.

____ 13. Organisms that cannot make their own food and must obtain energy from the foods they eat are called
a. autotrophs.
b. heterotrophs.
c. thylakoids.
d. plants.

____ 14. Photosynthesis uses sunlight to convert water and carbon dioxide into
a. oxygen.
b. high-energy sugars.
c. ATP and oxygen.
d. oxygen and high-energy sugars.

____ 15. Plants gather the sun's energy with light-absorbing molecules called
a. pigments.
b. thylakoids.
c. chloroplasts.
d. glucose.

____ 16. Plants take in the sun's energy by absorbing
a. high-energy sugars.
b. chlorophyll a.
c. chlorophyll b.
d. sunlight.

____ 17. Where are photosystems I and II found?
a. in the stroma
b. in the thylakoid membrane
c. in the Calvin cycle
d. all of the above

____ 18. The Calvin cycle is another name for
a. light-independent reactions.
b. light-dependent reactions.
c. photosynthesis.
d. all of the above

____ 19. What is a product of the Calvin cycle?
a. oxygen gas
b. ATP
c. high-energy sugars
d. carbon dioxide

____ 20. Which of the following affects the rate of photosynthesis?
a. water
b. temperature
c. light intensity
d. all of the above

Completion
Complete each statement.

21. Photosynthesis requires light, water, carbon dioxide, and _____.
22. In many plants, the rate of photosynthesis _____ when the weather becomes very cold.
23. Organisms, such as hawks and leopards, that obtain energy from the foods they consume are called _____.
24. Photosynthesis uses the energy of sunlight to convert water and carbon dioxide into oxygen and _____.
25. The light-dependent reactions convert NADP+ and ADP into the energy carriers NADPH and _____.

Short Answer

26. What is ATP, and when is energy released from it?
27. Write the overall equation for photosynthesis in both symbols and words.
28. What does the Calvin cycle do?
29. What is the difference between an autotroph and a heterotroph? Give an example of each type of organism.
30. List two factors that affect the rate of photosynthesis.

Essay

31. With as much detail as possible, describe what happens during the light dependent reactions of photosynthesis

32. With as much detail as possible, describe what happens during the light independent reactions of photosynthesis (The Calvin cycle).

Chapter 9 Test – Respiration **version a**

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Which of the following is NOT a stage of cellular respiration?
a. fermentation
b. electron transport
c. glycolysis
d. Krebs cycle

____ 2. What are the reactants in the equation for cellular respiration?
a. oxygen and lactic acid
b. carbon dioxide and water
c. glucose and oxygen
d. water and glucose

____ 3. The starting molecule for glycolysis is
a. ADP.
b. pyruvic acid.
c. citric acid.
d. glucose.

____ 4. Which process is used to produce beer and wine?
a. lactic acid fermentation
b. glycolysis
c. alcoholic fermentation
d. the Krebs cycle

____ 5. The conversion of pyruvic acid into lactic acid requires
a. alcohol.
b. oxygen.
c. ATP.
d. NADH.

____ 6. Which organism is NOT likely to carry out cellular respiration?
a. tree
b. mushroom
c. anaerobic bacterium
d. tiger

____ 7. During one turn, the Krebs cycle produces
a. oxygen.
b. lactic acid.
c. electron carriers.
d. glucose.

____ 8. Which of the following passes high-energy electrons into the electron transport chain?
a. NADH and FADH2
b. ATP and ADP
c. citric acid
d. acetyl-CoA

____ 9. Breathing heavily after running a race is your body's way of
a. making more citric acid.
b. repaying an oxygen debt.
c. restarting glycolysis.
d. recharging the electron transport chain.

____ 10. All of the following are sources of energy during exercise EXCEPT
a. stored ATP.
b. alcoholic fermentation.
c. lactic acid fermentation.
d. cellular respiration.

____ 11. Which process does NOT release energy from glucose?
a. glycolysis
b. photosynthesis
c. fermentation
d. cellular respiration

____ 12. Photosynthesis is to chloroplasts as cellular respiration is to
a. chloroplasts.
b. cytoplasm.
c. mitochondria.
d. nucleus.

____ 13. Which of the following is released from glucose during cellular respiration?

a. oxygen
b. light
c. energy
d. lactic acid

____ 14. Cellular respiration releases energy by breaking down
a. food molecules.
b. ATP.
c. carbon dioxide.
d. water.

____ 15. Which of these is a product of cellular respiration?
a. oxygen
b. water
c. glucose
d. all of the above

____ 16. Glycolysis provides a cell with a net gain of
a. 2 ATP molecules.
b. 4 ATP molecules.
c. 18 ATP molecules.
d. 36 ATP molecules.

____ 17. The two main types of fermentation are called
a. alcoholic and aerobic.
b. aerobic and anaerobic.
c. alcoholic and lactic acid.
d. lactic acid and anaerobic.

____ 18. In the presence of oxygen, glycolysis is followed by
a. lactic acid fermentation.
b. alcoholic fermentation.
c. photosynthesis.
d. the Krebs cycle.

____ 19. Cellular respiration is called an aerobic process because it requires
a. light.
b. exercise.
c. oxygen.
d. glucose.

____ 20. The starting molecule for the Krebs cycle is
a. glucose.
b. NADH.
c. pyruvic acid.
d. coenzyme A.

____ 21. In eukaryotes, aerobic respiration occurs in the
a. mitochondria.
b. chloroplasts.
c. cell membrane.
d. cytoplasm.

____ 22. The energy of the electrons passing along the electron transport chain is used to make
a. lactic acid.
b. citric acid.
c. alcohol.
d. ATP.

____ 23. When the body needs to exercise for longer than 90 seconds, it generates ATP by carrying out
a. lactic acid fermentation.
b. alcoholic fermentation.
c. cellular respiration.
d. glycolysis.

____ 24. Unlike photosynthesis, cellular respiration occurs in
a. animal cells only.
b. plant cells only.
c. all but plant cells.
d. all eukaryotic cells.

____ 25. The products of photosynthesis are the
a. products of cellular respiration.
b. reactants of cellular respiration.
c. products of glycolysis.
d. reactants of fermentation.

Completion
Complete each statement.

26. Cellular respiration occurs only in the presence of _____.

27. A high level of lactic acid in the blood is a sign that _____ fermentation has occurred.
28. Glycolysis converts glucose into two molecules of _____.
29. The _____ is a series of carrier proteins.
30. The body gets rid of lactic acid in a chemical pathway that requires _____.

Short Answer

31. List the three main stages of cellular respiration in order. Where does each stage take place in the cell?
32. What are the two types of fermentation? How do their products differ?
33. What role does oxygen play in the electron transport chain?
34. What happens during glycolysis?
35. What is the main function of the electron transport chain?
36. What roles does oxygen play in photosynthesis and in cellular respiration?

Essay

37. With as much detail as possible, describe the process of aerobic respiration starting with glucose.

Chapter 10 Test – Cell Growth and Division **version a**

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. As a cell becomes larger, its
a. volume increases faster than its surface area.
b. surface area increases faster than its volume.
c. volume increases, but its surface area stays the same.
d. surface area stays the same, but its volume increases.

____ 2. All of the following are problems that growth causes for cells EXCEPT
a. DNA overload.
b. excess nutrients
c. obtaining enough food.
d. expelling wastes.

____ 3. Which of the following is NOT a way that cell division solves the problems of cell growth?
a. Cell division provides each daughter cell with its own copy of DNA.
b. Cell division increases the mass of the original cell.
c. Cell division increases the surface area of the original cell.
d. Cell division reduces the original cell's volume.

____ 4. When during the cell cycle are chromosomes visible?
a. only during interphase
b. only when they are being replicated
c. only during the M phase
d. only during the G1 phase

____ 5. When during the cell cycle is a cell's DNA replicated?
a. G1 phase
b. G2 phase
c. S phase
d. M phase

____ 6. Which event occurs during interphase?
a. The cell grows.
b. Centrioles appear.
c. Spindle fibers begin to form.
d. Centromeres divide.

____ 7. During which phase of mitosis do the chromosomes line up along the middle of the dividing cell?
a. prophase
b. telophase
c. metaphase
d. anaphase

____ 8. Which of the following represents the phases of mitosis in their proper sequence?
a. prophase, metaphase, anaphase, telophase
b. interphase, prophase, metaphase, anaphase, telophase
c. interphase, prophase, metaphase, telophase
d. prophase, metaphase, anaphase, telophase, cytokinesis

____ 9. The two main stages of cell division are called
a. mitosis and interphase.
b. synthesis and cytokinesis.
c. the M phase and the S phase.
d. mitosis and cytokinesis.

____ 10. Cancer is a disorder in which some cells have lost the ability to control their
a. size.
c. growth rate.

b. spindle fibers.
d. surface area.

____ 11. As a cell grows, it
a. places more demands on its DNA.
b. uses up food and oxygen more quickly.
c. has more trouble moving enough materials across its cell membrane.
d. all of the above

____ 12. Compared with small cells, large cells have more trouble
a. dividing.
b. producing daughter cells.
c. moving needed materials in and waste products out.
d. making copies of their DNA.

____ 13. The process by which a cell divides into two daughter cells is called
a. cell division.
b. metaphase.
c. interphase.
d. mitosis.

____ 14. Which of the following happens when a cell divides?
a. The cell's volume increases.
b. It becomes more difficult for the cell to get enough oxygen and nutrients.
c. The cell has DNA overload.
d. Each daughter cell receives its own copy of the parent cell's DNA.

____ 15. Which of the following is a phase in the cell cycle?
a. G1 phase
b. G2 phase
c. M phase
d. all of the above

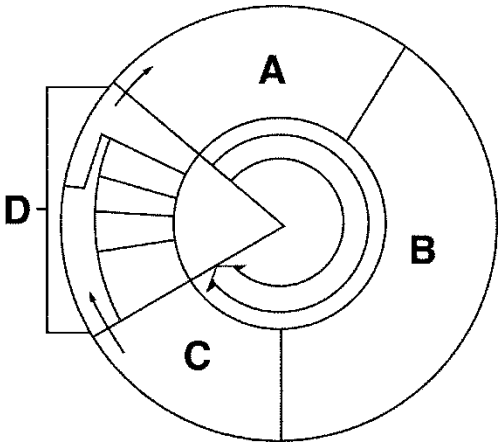

Figure 10–2

____ 16. Cell division is represented in Figure 10-2 by the letter?
a. A.
b. B.
c. C.
d. D

____ 17. The cell cycle is the
a. series of events that cells go through as they grow and divide.
b. period of time between the birth and the death of a cell.
c. time from prophase until cytokinesis.

d. time it takes for one cell to undergo mitosis.

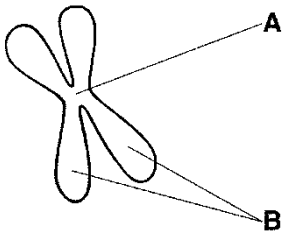

Figure 10–3

____ 18. The structure labeled A in Figure 10-3 is called the
a. centromere.
b. centriole.
c. sister chromatid.
d. spindle.

____ 19. The structures labeled B in Figure 10-3 are called
a. centromeres.
b. centrioles.
c. sister chromatids.
d. spindles.

____ 20. Which of the following is a phase of mitosis?
a. cytokinesis
b. interphase
c. anaphase
d. S phase

____ 21. The first phase of mitosis is called
a. prophase.
b. anaphase.
c. metaphase.
d. interphase.

____ 22. In which phase of mitosis do chromosomes become visible?
a. prophase
b. interphase
c. metaphase
d. telophase

____ 23. What happens when cells come into contact with other cells?
a. They divide more quickly.
b. They stop growing.
c. They produce cyclins.
d. They produce p53.

____ 24. In eukaryotic cells, the timing of the cell cycle is regulated by
a. the centrioles.
b. cyclins.
c. the spindle.
d. all of the above

____ 25. What is a tumor?
a. an accumulation of cyclins
b. a mass of cancer cells
c. the rapidly dividing cells found at the site of a wound
d. a defective p53 gene

Completion
Complete each statement.

26. The larger a cell becomes, the _____ efficiently it is able to function.

27. Before a normal cell becomes too large to carry out normal activities, it will usually divide to form two _____ cells.

28. The process by which a cell divides into two daughter cells is called _____.
29. Together, the G1 phase, S phase, and G2 phase are called _____.
30. Proteins called _____ regulate the timing of the cell cycle in eukaryotic cells.

Short Answer

31. What effect does cell size have on a cell's ability to efficiently carry out its activities? Give an example.
32. Describe how a plant cell produces a new cell wall during cytokinesis.
33. List two problems that growth causes for cells.
34. Why are chromosomes not visible in most cells except during cell division?

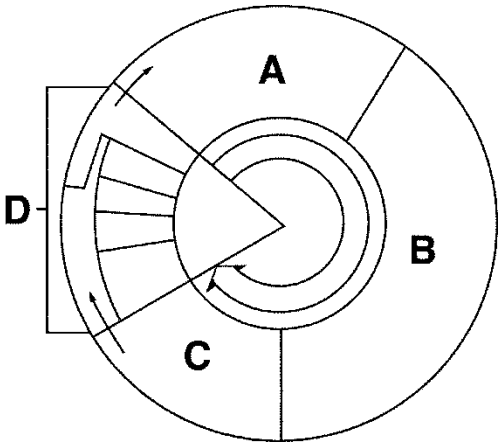

Figure 10–2

35. The main events of the cell cycle are labeled A, B, C, and D in Figure 10-2. Name these events. Then, briefly state what happens during each event.
36. How do cancer cells differ from normal cells?

Short Answer

37. With as much detail as possible, describe the process of cell division.

Chapter 11 Test – Introductions to Genetics and Meiosis version a

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Gregor Mendel used pea plants to study
a. flowering.
b. gamete formation.
c. the inheritance of traits.
d. cross-pollination.

____ 2. The chemical factors that determine traits are called
a. alleles.
b. traits.
c. genes.
d. characters.

____ 3. Gregor Mendel concluded that traits are
a. not inherited by offspring.
b. inherited through the passing of factors from parents to offspring.
c. determined by dominant factors only.
d. determined by recessive factors only.

____ 4. When Gregor Mendel crossed a tall plant with a short plant, the F_1 plants inherited
a. an allele for tallness from each parent.
b. an allele for tallness from the tall parent and an allele for shortness from the short parent.
c. an allele for shortness from each parent.
d. an allele from only the tall parent.

____ 5. The principle of dominance states that
a. all alleles are dominant.
b. all alleles are recessive.
c. some alleles are dominant and others are recessive.
d. alleles are neither dominant nor recessive.

____ 6. When Gregor Mendel crossed true-breeding tall plants with true-breeding short plants, all the offspring were tall because
a. the allele for tall plants is recessive.
b. the allele for short plants is dominant.
c. the allele for tall plants is dominant.
d. they were true-breeding like their parents.

____ 7. If a pea plant has a recessive allele for green peas, it will produce
a. green peas if it also has a dominant allele for yellow peas.
b. both green peas and yellow peas if it also has a dominant allele for yellow peas.
c. green peas if it does not also have a dominant allele for yellow peas.
d. yellow peas if it does not also have a dominant allele for green peas.

____ 8. When you flip a coin, what is the probability that it will come up tails?
a. 1/2
b. 1/4
c. 1/8
d. 1

____ 9. The principles of probability can be used to
a. predict the traits of the offspring produced by genetic crosses.
b. determine the actual outcomes of genetic crosses.
c. predict the traits of the parents used in genetic crosses.

d. decide which organisms are best to use in genetic crosses.

____ 10. Organisms that have two identical alleles for a particular trait are said to be
a. hybrid.
b. homozygous.
c. heterozygous.
d. dominant.

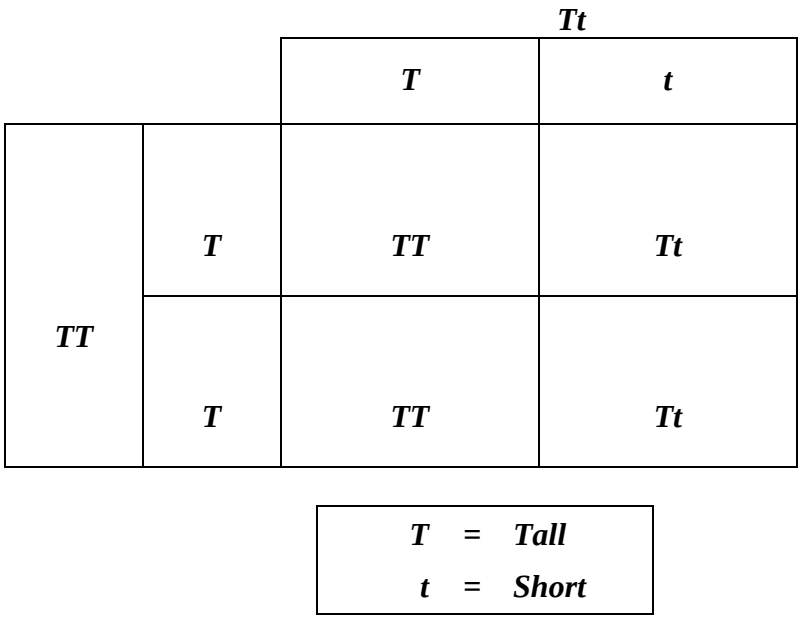

Figure 11–1

____ 11. In the Punnett square shown in Figure 11–1, which of the following is true about the offspring resulting from the cross?
a. About half are expected to be short.
b. All are expected to be short.
c. About half are expected to be tall.
d. All are expected to be tall.

____ 12. A Punnett square shows all of the following EXCEPT
a. all possible results of a genetic cross.
b. the genotypes of the offspring.
c. the alleles in the gametes of each parent.
d. the actual results of a genetic cross.

____ 13. What principle states that during gamete formation genes for different traits separate without influencing each other's inheritance?
a. principle of dominance
b. principle of independent assortment
c. principle of probabilities
d. principle of segregation

____ 14. How many different allele combinations would be found in the gametes produced by a pea plant whose genotype was *RrYY*?
a. 2
b. 4
c. 8
d. 16

____ 15. If a pea plant that is heterozygous for round, yellow peas (*RrYy*) is crossed with a pea plant that is homozygous for round peas but heterozygous for yellow peas (*RRYy*), how many different phenotypes are their offspring expected to show?
a. 2
b. 4
c. 8
d. 16

____ 16. Situations in which one allele for a gene is not completely dominant over another allele for that gene are called
a. multiple alleles.
b. incomplete dominance.
c. polygenic inheritance.
d. multiple genes.

____ 17. A cross of a black chicken (*BB*) with a white chicken (*WW*) produces all speckled offspring (*BBWW*). This type of inheritance is known as
a. incomplete dominance.
b. polygenic inheritance.
c. codominance.
d. multiple alleles.

____ 18. Variation in human skin color is an example of
a. incomplete dominance.
b. codominance.
c. polygenic traits.
d. multiple alleles.

____ 19. If an organism's diploid number is 12, its haploid number is
a. 12.
b. 6.
c. 24.
d. 3.

____ 20. Gametes have
a. homologous chromosomes.
b. twice the number of chromosomes found in body cells.
c. two sets of chromosomes.
d. one allele for each gene.

____ 21. Gametes are produced by the process of
a. mitosis.
b. meiosis.
c. crossing-over.
d. replication.

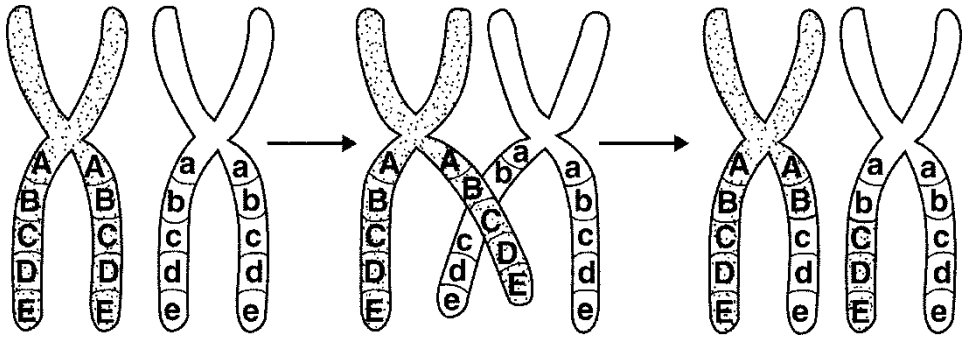

Figure 11–3

____ 22. What is shown in Figure 11–3?
a. independent assortment
b. anaphase I of meiosis
c. crossing-over
d. replication

____ 23. Unlike mitosis, meiosis results in the formation of
a. diploid cells.
c. 2N daughter cells.

b. haploid cells.
d. body cells.

____ 24. Linked genes
a. are never separated.
c. are on the same chromosome.
b. assort independently.
d. are always recessive.

____ 25. If two genes are on the same chromosome and rarely assort independently,
a. crossing-over never occurs between the genes.
b. crossing-over always occurs between the genes.
c. the genes are probably located far apart from each other.
d. the genes are probably located close to each other.

Completion
Complete each statement.

26. The different forms of a gene are called _____.

27. If you flip a coin five times and it comes up heads each time, the probability that it will come up heads the next time is _____.

		Tt	
		T	***t***
TT	***T***	***TT***	***Tt***
	T	***TT***	***Tt***

T	**=**	***Tall***
t	**=**	***Short***

Figure 11–1

28. In the Punnett square shown in Figure 11–1, the genotypes of the offspring are _____.

29. When two heterozygous tall pea plants are crossed, the expected genotype ratio of the offspring is _____.

30. Crossing a pink-flowered four o'clock with a white-flowered four o'clock will produce pink-flowered offspring and _____-flowered offspring.

Short Answer

31. How many recessive alleles for a trait must an organism inherit in order to exhibit that trait?
32. What might happen if the gametes of a species had the same number of chromosomes as the species' body cells?
33. How many sets of chromosomes are in a diploid cell?
34. What happens to the number of chromosomes per cell during meiosis?
35. Contrast the cells produced by mitosis with those produced by meiosis.

Essay

36. In as much detail as possible, summarize the process of meiosis. You may draw pictures if you wish.

Chapter 12 Test - DNA, RNA and Protein Synthesis **version a**

Multiple Choice
Identify the choice that best completes the statement or answers the question.

____ 1. Which of the following is a nucleotide found in DNA?
a. ribose + phosphate group + thymine
b. ribose + phosphate group + uracil
c. deoxyribose + phosphate group + uracil
d. deoxyribose + phosphate group + cytosine

____ 2. Because of base pairing in DNA, the percentage of
a. adenine molecules in DNA is about equal to the percentage of guanine molecules.
b. pyrimidines in DNA is about equal to the percentage of purines.
c. purines in DNA is much greater than the percentage of pyrimidines.
d. cytosine molecules in DNA is much greater than the percentage of guanine molecules.

____ 3. In eukaryotes, DNA
a. is located in the nucleus.
b. floats freely in the cytoplasm.
c. is located in the ribosomes.
d. is circular.

____ 4. DNA is copied during a process called
a. replication.
b. translation.
c. transcription.
d. transformation.

____ 5. During DNA replication, a DNA strand that has the bases CTAGGT produces a strand with the bases
a. TCGAAC.
b. GATCCA.
c. AGCTTG.
d. GAUCCA.

____ 6. RNA contains the sugar
a. ribose.
b. deoxyribose.
c. glucose.
d. lactose.

____ 7. Unlike DNA, RNA contains
a. adenine.
b. uracil.
c. phosphate groups.
d. thymine.

____ 8. How many main types of RNA are there?
a. 1
b. 3
c. hundreds
d. thousands

____ 9. Which type(s) of RNA is(are) involved in protein synthesis?
a. transfer RNA only
b. messenger RNA only
c. ribosomal RNA and transfer RNA only
d. messenger RNA, ribosomal RNA, and transfer RNA

____ 10. What is produced during transcription?
a. RNA molecules
b. DNA molecules
c. RNA polymerase
d. proteins

____ 11. During transcription, an RNA molecule is formed

a. that is complementary to both strands of DNA.
b. that is identical to part of a single strand of DNA.
c. that is double-stranded.
d. inside the nucleus.

____ 12. How many bases are needed to specify one amino acid?
a. 3
b. 6
c. 9
d. 12

____ 13. What happens during the process of translation?
a. Messenger RNA is made from DNA.
b. The cell uses information from messenger RNA to produce proteins.
c. Transfer RNA is made from messenger RNA.
d. Copies of DNA molecules are made.

____ 14. Genes contain instructions for assembling
a. purines.
b. nucleosomes.
c. proteins.
d. pyrimidines.

____ 15. Which type of RNA functions as a blueprint of the genetic code?
a. rRNA
b. tRNA
c. mRNA
d. RNA polymerase

____ 16. Which of the following statements is false?
a. Some genes code for enzymes.
b. The instructions for making some proteins are not specified by genes.
c. An organism's inherited traits depend on proteins.
d. An organism's genes determine its inherited traits.

____ 17. A mutation that involves one or a few nucleotides is called a(an)
a. chromosomal mutation.
b. inversion.
c. point mutation.
d. translocation.

____ 18. Which of the following is NEVER a frameshift mutation?
a. substitution
b. insertion
c. deletion
d. point mutation

____ 19. A promoter is a
a. binding site for DNA polymerase.
b. binding site for RNA polymerase.
c. start signal for transcription.
d. stop signal for transcription.

____ 20. When *E. coli* is grown on glucose,
a. lactose molecules bind to the *lac* repressor.
b. the *lac* repressor binds to the operator of the *lac* operon.
c. RNA polymerase binds to the promoter of the *lac* operon.
d. the *lac* genes are transcribed.

____ 21. Hox genes determine an animal's
a. basic body plan.
b. size.
c. skin color.
d. eye color.

____ 22. Which of the following statements is false?
a. Mutations do not occur in hox genes.
b. Hox genes that are found in different animals are very different from each other.
c. Hox genes control the normal development of an animal.
d. Hox genes occur in clusters.

____ 23. What enzyme is responsible for separating complimentary strands of DNA for replication?
a. Helicase
b. Catalase
c. RNA polymerase
d. DNA polymerase

____ 24. What enzyme is responsible for linking individual nucleotides into DNA molecules
a. Helicase
b. Catalase
c. RNA polymerase
d. DNA polymerase

____ 25. An expressed gene is one that
a. functions as a promoter
b. is transcribed into RNA
c. codes for only one amino acid
d. is made of mRNA

Completion
Complete each statement.

26. In DNA, _____ and _____ are pyrimidines.

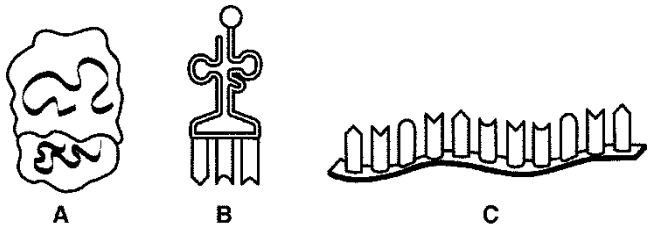

Figure 12–3

27. In Figure 12–3, A, B, and C are three types of _____.

28. The order of nitrogenous bases in DNA determines the order of _____ in proteins.

29. The codon that signals the end of a growing polypeptide is called a (an) _____.

30. In DNA, _____ and _____ are purines.

Short Answer

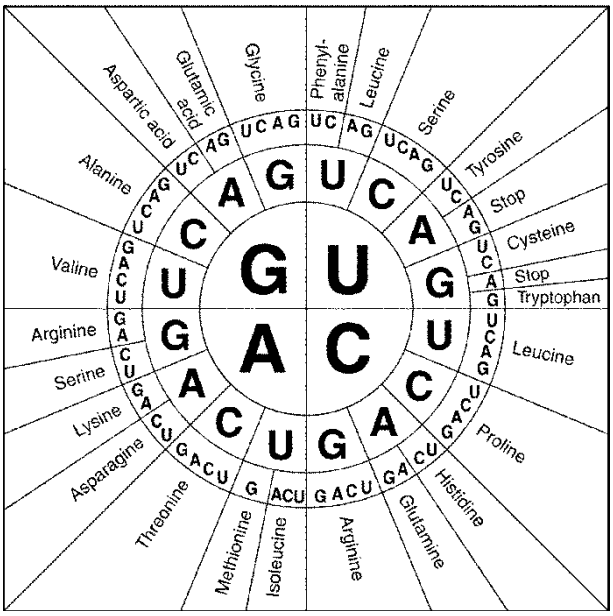

Figure 12–2

31. What amino acid sequence does the following **D**NA sequence code for?
    TACCATGAACCAATC
32. What causes translation to stop?
33. What are the three main parts of a DNA nucleotide?
34. Describe the function of DNA
35. What are two differences between DNA and RNA?
36. What is a mutation?

Essay

37. Describe in as much detail as possible, what happens during DNA replication.
38. Describe in as much detail as possible, what happens during transcription
39. Describe in as much detail as possible, what happens during Protein Synthesis

APPENDIX G

STUDENT INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

Student Engagement: When students are engaged, they make a investment in learning. They try hard to learn what class offers. They take pride not simply in earning the formal indicators of success (grades), but in understanding the material and incorporating or internalizing it in their lives

Confidence:

1. Do you feel confident in your ability to learn science content?
2. How have you performed in science classes in the past?
3. Is there anything about science content that can make it intimidating? Can you describe that?
4. What kind of class activities help you learn best?
5. How did the recent hands-on activities effect your confidence in the material
6. Did having access to models and manipulatives help your performance on the test?

Engagement:

1. Which of your classes do you find most engaging?
2. What makes a class engaging or not engaging?
3. What kind of class activities do you find most engaging?
4. Can you describe an specific examples of activities that you found engaging?
5. What kind of activities do you find to be disengaging?
6. Can you describe the engagement levels of the recent hands-on modeling activities (photosynthesis modeling, respiration modeling and mitosis modeling.)

Understanding:

1. Summarize the process of photosynthesis to the best of your ability.
2. Summarize the process of cellular respiration to the best of your ability.
3. Describe what happens to cells during the processes of mitosis and meiosis. What is the function of each and how do they differ?
4. To the best of your ability, describe what happens in DNA replication. How does it happen?
5. To the best of your ability, describe what happens during DNA transcription. How does it happen?
6. To the best of your ability, describe how proteins are made from an mRNA template.

APPENDIX H

IRB EXEMPTION

MONTANA
STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
c/o Veterinary Molecular Biology
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
406-994-6783
cherylj@montana.edu

MEMORANDUM

TO: Joseph Ruffatto

FROM: Mark Quinn, Ph.D. Chair Mark Quinn CJ
Institutional Review Board for the Protection of Human Subjects

DATE: December 8, 2010

SUBJECT: *"The Impact of Manipulative Models on Student Understanding or, Engagement in, and Confidence in Abstract Biological Processes" [JR120810-EX]*

The above research, described in your submission of December 6, 2010, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal Regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b)(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

X (b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

___ (b)(3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b)(4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b)(5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b)(6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

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