TEACHING GENETICS USING HANDS-ON MODELS, PROBLEM SOLVING, AND
INQUIRY-BASED METHODS

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Biological Science-Interdepartmental-Master of Science

2013

ABSTRACT

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Teaching genetics can be challenging because of the difficulty of the content and misconceptions students might hold. This thesis focused on using hands-on model activities, problem solving, and inquiry-based teaching/learning methods in order to increase student understanding in an introductory biology class in the area of genetics. Various activities using these three methods were implemented into the classes to address any misconceptions and increase student learning of the difficult concepts.

The activities that were implemented were shown to be successful based on pre-post assessment score comparison. The students were assessed on the subjects of inheritance patterns, meiosis, and protein synthesis and demonstrated growth in all of the areas. It was found that hands-on models, problem solving, and inquiry-based activities were more successful in learning concepts in genetics and the students were more engaged than tradition styles of lecture.

ACKNOWLEDGMENTS

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INTRODUCTION

The world of biology contains many difficult concepts to understand, genetics being one of many. When deciding what unit to use for this study, complex topics were considered such as photosynthesis, cellular respiration, and enzyme function, but the unit of genetics and heredity was the selection. One of the reasons it was chosen was due to the disengagement of previous students with the topics of inheritance patterns, meiosis, Deoxyribonucleic acid or DNA, and protein synthesis, so the focus was set on these areas. The students have asked for more active learning activities and less lecture during this unit. Also, the world of education is ever changing, and with more emphasis being place on standardized test scores, this topic was chosen because it was the area where the students have exhibited lower scores in comparison to other topics in biology, according to the Michigan Merit Exam and the classroom assessments.

What the previous genetics unit lacked was engaging, active, and inquiry based activities. Previously, lecture with note taking, paper models, and genetics problems using pea plants as examples were used, but they did not seem to excite the students. Their lack of engagement showed as increase in complaints about the subject matter, and poor scores in informal and formal assessments. The hypothesis on which this

study is based is that the use of hands-on models, problem solving, and inquiry based teaching/learning methods will increase student engagement and achievement in genetics.

Theoretical Framework for Teaching Genetics

Students commonly carry misconceptions into their biology classes including those related to topics of genetics. The majority of the unit studied focused on meiosis and protein synthesis, very difficult concepts for students to understand. There are many examples of misconceptions or incomplete information students have concerning meiosis because it is very similar to mitosis, their complex relationship confuses students and makes it difficult for them to grasp the process(Harrell, 2001). Other concepts that confuse students regarding meiosis include: the structure of homologous chromosomes consisting of sister chromatids that carry the same allele and chromosome behavior during meiosis(Knippels, Waarlo, and Boersma, 2005). An understanding of the mechanism of DNA and genetics is essential to a thorough education in biology(Roberg, 2004).

The students have difficulty with understanding the flow of genetic information from DNA to protein. This is partially due to the fact that students cannot see the actual molecules

involved and the process itself with their eyes (Guzman and Bartlett, 2012).

In order to undo a misconception, students need to be able to support a valid scientific concept with evidence that contradicts the misconception(Lawson and Thompson, 1988). The goal of this project is remove all misconceptions and to connect all of these concepts in a complete fashion that is not above the student's heads; and to bring them to a level of general understanding of inheritance patterns, DNA structure, making proteins, and gametogenesis. A complete understanding of difficult topics in genetics can be achieved through using hands-on methods, problem solving, and inquiry based methods.

The three approaches of teaching/learning methods of hands-on models, problem solving, and inquiry are all interconnected and work together as a lattice in many ways. The problem-solving approach to science instruction has the potential to engage students in authentic investigations and develop their inquiry skills(Chiapetta, 1997). Teaching science as inquiry stresses active learning and the importance of understanding a science topic(ibid.). Both of the previous statements, show how the relationship among the use of active learning techniques and problem solving strategies are inherently used as methods to teach inquiry-based science.

Each method has extensive research behind it that have shown to be successful in the classroom.

Many methods have been used to teach chromosomal relationships and movement during meiosis. Some have been successful while others have not. One technique that faltered was using computer animations to show the processes of meiosis and protein synthesis. It failed due to the fact that it was a passive process(Locke and MerDermid, 2005). Meiosis needs to be taught through an active/tactile process. Extensive educational research has demonstrated that student learning improves when students are actively engaged(Guzman and Bartlett, 2012).

The expectation is that comprehension increases when students can visualize the process and actively move chromosome models through the process of meiosis in a kinesthetic way with their hands(Barnhart and Farrar, 2011). Also, students using their hands to construct a model are likely to have their minds engaged and become intimately familiar with the vocabulary of molecular biology(Malacinski and Zell, 1996). Both of these research groups, have confirmed that using hand-on chromosomal models leads to a greater understanding of meiosis compared to other methods.

Another learning strategy that can be incorporated through using hands-on models is diagramming the process. The phases of meiosis can be illustrated as the students manipulate the models through the stages of meiosis. Students that graphically represent the relationships between chromosomes, genes, and alleles clarify how the concepts are related(Banet and Ayuso, 2000). A level of student understanding of meiosis was demonstrated by the students drawing the chromosomes and alleles during the phases.

Hand-on models can be manipulated by the students individually or in small groups. Large scale models can even be used in groups as large as the class itself. It was found that going through the process of meiosis as a class, may increase both knowledge and recall(Marzano, Pickering, and Pollock 2001).

In addition, a basic understanding of genetics and heredity involves problem solving. Problem solving is essential to student achievement because it requires a deeper understanding of the material(White, Bolker, Koolar, Ma, Maw, and Yu, 2007). The nature of problem solving consists of four stages: problem identification, solution generation, solution evaluation, and solution execution(Friedel, Irani, Rhoades, Fuhrmann, and Gallo, 2008)

Also, it has been found that students construct their understanding by solving real world problems(Crawford, 2000). It is imperative in teaching genetics to use problem solving strategies to deepen understanding, and the students will retain more knowledge by constructing their own framework of how traits are inherited. The problems also need to be relevant to the students lives in order to improve retention.

Practice and repetition have to be incorporated into problem solving methods in order for them to be effective learning techniques. It requires considerable knowledge and practice through solving many similar genetics problems to become successful at this kind of problem solving(Smith and Good, 1984). As in mathematics, students would not learn a process by solving one problem. Learning takes place through solving many problems. The same is true in the field of genetics. When developing problem solving strategies in genetics, it is required that the students solve many inheritance problems with frequent checks of understanding in between problems in order to build a solid understanding of how traits are based down from parent to offspring.

Inquiry-based methods are common teaching strategies used in science education. The Next Generation Science Standards are promoting science practices or inquiry in the classroom.

It has been stated that inquiry is the "central strategy for teaching science"(Keys and Bryan, 2001). It has been found that very few students have a good understanding of the way science is completed because of their lack in experience in engaging in scientific inquiry(Campbell, Der, Wolf, Packenjam, and Adb-Hamid, 2012). An increase in the amount of inquiry based activities in the classroom, where a problem is posed and science process skills are used to try to rationalize the problem, is correlated with an increase in understanding of scientific concepts such as genetics.

Inquiry is used to promote activity-oriented learning that reflects scientific investigation, specifically by using observation, experimentation, and reasoning as practiced by scientists(Chiappetta and Adams, 2004). To meet this instructional goal, labs that use basic science process skills need to be integrated. It is difficult to find inquiry-based labs in the area of genetics. However, Fast Plants® or *Brassica rapa* have been used to teach genetics for a variety of reasons including their short life cycle, genetic diversity, and lack of ability to self pollinate(Wendell and Pickard, 2013). Guided inquiry labs can easily be completed by using Fast Plants® and observing the traits in subsequent generations.

It has been found that students using an inquiry based approach score higher on standardized assessments, improve their science process skills, and have more positive attitudes toward science(Gibson and Chase, 2002). In order to improve levels of understanding and assessment scores, inquiry-based activities are a must. It has been found that many types of activities promote inquiry in the classroom. Guided inquiry lab experiments, hand-on models, and problem solving are included in these type of activities. These types of activities have resulted in an improvement in student achievement and learning by many educators.

The Science behind Genetics

Meiosis is the process by which chromosomes divide to form gametes or sex cells. Meiosis is much different from mitosis yet similar at the same time. The process is different from mitosis because four cells are produced instead of two and they are genetically different. There are two reasons why they are genetically different. One reason is because they cells divide twice, completely separating all the gene pairs in the cells. The cells originate as diploid(2N)and result into four haploid(1N) cells at the end of both divisions, where N is the number of chromosomes in an organism. For example, if a person was heterozygous for a characteristic, two of the

gametes produced through meiosis would have the dominant trait while the other two would have the recessive. The possible combinations of chromosomes in a human gamete is 2^N, where N equals 23. That means that 2^{23} equals over eight million possible combination of chromosomes in an egg or sperm. Also, the chromosomes cross over and exchange pieces of chromosome during meiosis. In this process, the homologous chromosomes become tangled as they cross over; when they split apart, what was once the paternal chromosome has a part of the maternal attached and the maternal chromosome has part of the paternal attached.

A monk named, Gregor Mendel, is the father of modern genetics and heredity. In the 1800's, he used pea pods to study heredity(Campbell, 2002). He looked at characteristics like plant size and pea color, which we now call phenotypes and conducted test crosses to observe what the characteristics of the offspring would be in the next generation. The two plants that are crossed are called the parent generation and the first generation offspring was call the F1 generation. What he saw was that there was one trait that showed up more than the other. For example, there were more green colored peas than yellow. He called this the principle of dominance.

Also, he concluded that parents contain two alleles for a trait and they only pass on one of the two alleles to their offspring. This law he called the law of segregation, the two alleles segregate from one another during gamete(egg or sperm)formation which is based on meiosis. An allele is a form of a trait and for a single gene characteristic it can be either dominant or recessive.

Characteristics also have genotypes. The genotype consists of the two alleles that are inherited by offspring for a discrete characteristic. Since two parents can have offspring with different phenotypes or physical characteristics, it means that in this case the parents each had a hidden allele called the recessive allele in their genotype for that characteristic. Also, the parent genotypes must be heterozygous or carriers where they have a dominant and recessive allele for the gene and show the dominant phenotype. This is considered the norm.

Mendel also concluded that characteristics on different chromosome pairs are inherited independent of one another. When gametes form, one allele for each characteristic is passed to the daughters cells. When a parent produces a gamete the chromosomes containing the genes independently assort from one another, so each gamete only contains one chromosome of a

homologous pair instead of two. The cell division that occurs
to produce gametes is called meiosis.

    There are instances where alleles interact in ways to
produce proteins, whose patterns differ from typical dominant
and recessive inheritance patterns. These allele combinations
can result in more than two phenotypes. Co-dominance is an
example of inheritance that differs from the norm. Co-
dominance is when two alleles are dominant for a trait and are
expressed in such a way that the combination of two alleles is
different than either homozygote. An example is blood type.
When a person inherits alleles for A and B blood the person has
AB blood instead of one dominating over the other. The alleles
A and B are co-dominant. Blood typing is also interesting
because it is an example of multiple alleles. There are three
possible alleles that determine blood type instead of two,
although humans still inherit two. Multiple alleles allows for
more than two phenotypes and three genotypes to be inherited.
Incomplete dominance is different than normal dominant
recessive inheritance because there are only two alleles for a
trait but neither is dominant. When the two traits are
inherited together they blend into a new phenotypes. For
example, incomplete dominance is shown by crossing red flowers
and white flowers to produce pink flowers. Some

characteristics are polygenetic where there are many genes that determine the phenotype for that characteristic. Examples of polygenetic characteristics are hair, eye, and skin color. Humans carry more than one gene for these traits and the blending of allele products results in multiple phenotypes.

In 1953, it was found that DNA's chemical structure actually looks like a double helix by Watson and Crick(Campbell, 2002). The sides to the DNA helix are repeating phosphate and sugar chain, but the rungs are made of nitrogen base pairs. Adenine always binds with Thymine making two hydrogen bonds and Cytosine always binds with Guanine making three hydrogen bonds. The difference between the number of bonds is why adenine does not make a chemical bond to cytosine. Every human being has a different sequence of bases on their DNA. The 3 billion bases for the human genome contains around 25,000 genes(Roberg, 2004). All human Genomes are 99.9% the same, but that 0.1% accounts for all of our differences(Miller and Levine, 2004).

The sequence of nucleotides of DNA contains the information necessary to make the building blocks of our body which are proteins. A DNA molecule is too big to fit out of the nuclear pores to get to the ribosomes to make the protein. Instead, DNA is transcribed into messenger RNA using an enzyme

called RNA polymerase. Ribonucleic Acid or RNA is single
stranded and contains the nitrogen base uracil instead of
thymine as in the case in DNA. The messenger ribonucleic acid
or mRNA strand, when complete, travels into the cytoplasm to a
ribosome. The ribosome "reads" the mRNA sequence by connecting
transfer ribonucleic acid or tRNA molecules with an amino acid
attached to them. Every three bases on the mRNA strand is
called the codon. The codon binds to three complementary bases
on the tRNA called the anticodon. The codon on the mRNA and
anticodon on the tRNA specify a particular amino acid. The
amino acids brought to the ribosome link together using peptide
bonds until the protein chain in complete. Once the protein
chain is complete it can be used by the cell or sent to other
parts of the body. Occasionally, a change in the DNA sequence
will occur which is called a mutation. The mutation can change
the protein by altering which amino acid is in the protein
sequence.

Demographics

This study occurred at Grass Lake High School. The
village of Grass Lake is located between Ann Arbor and Jackson
on I-94. It has a population of 1,173 people. It is a farming
based community, but urban sprawl and new subdivisions have
changed the demographics of the area in recent years. People

commute to Jackson, Ann Arbor, Detroit, and Lansing from Grass

Lake. There are 404 students at the high school, which is

96.3% Caucasian, 1.7% Hispanic, 0.7% Native American, 0.5%

African American, and 0.5% Asian(usaschoolinfo, 2013). Last

year, 84 students qualified for free and reduced lunch(iteach,

2013). The factor that separates students is socioeconomic

class. Many students have families that have lived in the area

for many years and own family businesses and farms. There are

some families from the Ann Arbor area that are looking for more

affordable housing. Grass Lake High School accommodates a

range of students from those who live on public assistance to

students whose parents have doctoral degrees.

Grass Lake district's goal is be able to compete

academically at the level of our neighboring school district in

Chelsea, Mi. Last year, Grass Lake High School student's ACT

scores were amongst the highest in the county. The expectation

is that the students that graduate from Grass Lake will be

ready for a university education.

Three introductory biology classes were used for this

research project. These classes consisted of two ninety minute

semester long block classes and one fifty-five minute class

that ran the entire year. Seventy consent forms were

submitted, providing permission to use their classroom data.

Out of those seventy students only one had special needs.

IMPLEMENTATION

In preparation of this study, six weeks were spent during the summer of 2012, researching different strategies and activities expected to be successful in teaching the themes within the unit of genetics. Activities that used inquiry, hands-on models, and problem solving were targeted for inclusion in this unit. Many hours were dedicated to building new activities/models, and other activities that other teachers have used were adapted.

On the first day of school the students were given the parental consent forms(Appendix I) and informed that the instructor was conducting research this year in her classes in order to write a thesis the following summer. The consent forms were not accessed the entire year until the grades were completed. The new genetics unit started after we covered cells, cell division, and mitosis. The unit began with a pre-test assessment to gather information of the students prior knowledge as the main objective. The pre and post-tests(Appendix II A) were identical and consisted of twelve open ended questions that were scored according to a rubric(Appendix II B). The scores awarded ranged from 0 through 3 points for each question. A score of 0 indicated that the student did not complete the question or their answer showed a misconception. A score of 1 indicated that the

student showed a basic understanding of the question. A score

of 2 indicated that the student showed a developing

understanding beyond the basic. A score of 3 indicated that

the student showed a mastery of the concept with a complete

answer that included all of the relevant information. The

sequence of activities that were implemented into this unit

after the pre-test are shown in Table 1. Also included in this

table as a curricular guide throughout the unit are the

Michigan objectives and an indicator if the activity used

hands-on models, problem solving, and inquiry.

Table 1: Sequence of Activities and Objectives. This table
includes all activities and objectives addressed during the
genetics unit and their category as a hands-on model, problem
solving, or Inquiry based activity. See Appendix I B for
objective descriptions.

Day	State Objectives addressed	Activity	Hands-On Models (M) Problem Solving (PS) Inquiry (I)
Day 1	**B4.1A, B4.1B, B4.1C, B4.1D, B4.1E, B4.2A, B4.2B, B4.2C, B4.2D. B4.2E, B4.2F, B4.2G, B4.3A, B4.3B, B4.3C, B4.3D, B4.3E, B4.3F, B4.3G**	Pre-test	
Day 2	**B4.1A, B4.1B, B4.1C, B4.1D, B4.1E**	Mendelian Genetics Using Sponge Bob Problems and Begin Brassica/Fast Plant® Genetics Lab	PS, I

Table 1: Cont'd

Day			
Day 3	**B4.1A, B4.1B, B4.1C, B4.1D, B4.1E**	Mendelian Genetics Using Sponge Bob Part 2 SeaWorld Dihybrid cross activity	PS
Day 4	**B4.1A, B4.1B, B4.1C, B4.1D, B4.1E**	Take Data and writing Results and Conclusions for Fast Plant® Lab	I
Day 5	**B4.3A, B4.3B, B4.3C, B4.3D, B4.3E, B4.3F, B4.3G**	Meiosis Activity with Pool Noodles Meiosis Model Activity	M
Day 6	**B4.3A, B4.3B, B4.3C, B4.3D, B4.3E, B4.3F, B4.3G**	Meiosis Activity Part 2	M
Day 7	**B4.2A, B4.2B, B4.2C, B4.2D. B4.2E**	Superclam Activity	PS
Day 8	**B4.2A, B4.2B, B4.2C, B4.2D. B4.2E, B4.2F, B4.2G**	Protein Synthesis Models	M
Day 9	**B4.2A, B4.2B, B4.2C, B4.2D. B4.2E, B4.2F, B4.2G**	Protein Synthesis Models Part 2	M
Day 10	**B4.1A, B4.1B, B4.1C, B4.1D, B4.1E**	Sponge Bob Incomplete Dominance Activity Blood Typing Murder Mystery Activity	PS
Day 11	**B4.1A, B4.1B, B4.1C, B4.1D, B4.1E, B4.2A, B4.2B, B4.2C, B4.2D. B4.2E, B4.2F, B4.2G, B4.3A, B4.3B, B4.3C, B4.3D, B4.3E, B4.3F, B4.3G**	Post-test	

Description of Activities

Fast Plant® Investigation (Appendix III A) Guided Inquiry Activity

In this activity, the students observed mendelian genetic concepts by studying Fast Plants®. The characteristic/phenotype they observed was stem color. This experiment was organized using a guided inquiry format where students were to make predictions/hypotheses about which stem color was the dominant or recessive trait, and determine the outcomes of the parental cross and f1 crosses. The students were separated into three groups. One group of students germinated the parental generation, the second group germinated the F1 generation, and the third group germinated the F2 generation. Once the seeds sprouted over the course of three days, the students collected the qualitative data of stem color for the three generations and compiled it as a class. After the data collection was completed the students continued with the discussion and conclusions, where it was determined that purple stem color was dominant over green stem color. The expected phenotypic ratios of the offspring for the F1 and F2 generation were calculated using punnett squares and compared to the actual data collected.

Sponge Bob Genetics(Trimpe, 2003)Problem Solving Activity

In this unit, problem solving activities were implemented that used a familiar test subject, "Sponge Bob". The concepts addressed in this activity were dominant and recessive alleles, homozygous and heterozygous pairs; and test crosses/punnett squares were conducted to determine expected outcomes. The students conducted the Sponge Bob crosses and calculate the genotypic and phenotypic ratio and percentages of offspring with certain alleles. The students were given different scenarios using Sponge Bob and his friends as examples in order to give them a variety of problems in repetition without it becoming tedious. The students were more interested and engaged in these problems than when data from pea crosses were used in the past.

SeaWorld Dihybrid Cross Activity(Busch Gardens, 2003)Problem Solving Activity

A previously used activity, hamster characteristics, was used to demonstrate dihybrid crosses, but needed updating. This activity from the SeaWorld website focused on five different crosses using all kinds of unique animals as test subjects. Students worked in groups and completed the dihybrid crosses. They answered questions about the cross after completing the

punnett squares. The students had to calculate phenotypic and genotypic ratios of the offspring.

Pool Noodle Chromosomes modeling Meiosis (Appendix III B)

Hands-on Model Activity

This activity was developed using pool noodles as "chromosomes". Using guidelines from a workshop on "chromonoodles", attended at the National Science Teachers Association Conference, two sets of three homologous pairs were constructed, complete with Velcro "alleles". The students chose which characteristics were represented by the alleles. The class completed the two phases of meiosis using the pool noodle models. All twelve noodles were distributed to different students, who were in charge of their movement through meiosis. At the end of the process, the chromosomes from all four "gametes" were in separate piles on the floor. At the end, the students in groups of four wrote down the alleles represented in the four cells, an egg and three polar bodies. The students also wrote down what physical characteristic/phenotype information that egg would carry as represented by that allele. In the last part of this activity, the students were given alleles from a sperm that their egg would be "joining" during fertilization. The students had to

combine the alleles from the two gametes and determine the allele combination in the offspring.

Meiosis Models (Appendix III B) Hands-on Model Activity

In this activity, craft foam and Velcro were used to make chromosome models, replacing paper models previously used. In pairs, students manipulated three homologous pairs through the phases of meiosis. This occurred after an in-depth class discussion of gamete formation and the phases of meiosis. The students were to physically manipulate the models through meiosis one and meiosis two, drawing the chromosomes at certain key phases during these processes.(Appendix III D) These drawings helped students see how chromosomes line up differently during meiosis one and two, demonstrating how gametes have different genetic combinations. At the end of the activity the students answered discussion questions to demonstrate whether or not they understood the entire process.

Protein Synthesis Models (Appendix III C) Hands-on Model Activity

Protein synthesis kits were constructed from craft foam and Velcro. The kits include a DNA backbone, mRNA backbone, nitrogen bases(nucleotides), tRNA, amino acids, and peptide bonds. The students constructed a nine base DNA strand and

transcribed it into mRNA, which was used as a template for protein synthesis. During the activity, the students answered process questions and wrote down the DNA base sequence, mRNA codons, and amino acid sequence. After this activity was completed the students did it again in reverse to reinforce the processes. They started with three amino acids beginning with methionine, the start codon. Then, the students have to find the mRNA sequences and DNA that corresponded to the amino acid code.

"Super" Clam Activity (Appendix III D) Hands-on Model Activity

In this activity, students were given a real case study of a clam mutation. They were given a DNA sequence of a normal clam and a "super" clam that has a mutation that prevents it from being poisoned by red tide blooms. The students transcribed and translated the DNA sequences of the normal and "super" clam. After, the students answered questions about mutations and what type of mutation the "super" clam had and how this impacted evolution of the species. At the culmination of this activity, the students looked at a diagram of a food web that included the clam and answered questions about the impact the clam had on surrounding species. This activity was adapted from work completed by the Evo-Ed collaboration through Michigan State University(evo-ed.com).

Sponge Bob Incomplete Dominance Activity(Trimpe, 2003)Problem Solving Activity

In this activity, students discovered the allele interactions that differed from normal dominant and recessive inheritance through another Sponge Bob activity. This activity focused on genotype, phenotype, and crosses within the context of incomplete dominance. The students had to problem solve to determine the genotypic and phenotypic ratios of test crosses to determine how incomplete dominance is different from typical dominant and recessive inheritance.

Blood Typing Murder Mystery (Appendix III E)Problem Solving Activity

In this activity, students answered some basic questions about the genetics of blood type, multiple alleles, and co-dominance, and then completed a problem solving activity. The students read a mystery about a millionaire who died and a man who claimed to be his kin to collect his inheritance. The students were given the blood type of the millionaire and the alleged son. The students used the blood types to prove that the man was or was not his offspring by completing punnett squares.

RESULTS

The unit began with a pre-test and ended with a post-test, that consisted of twelve open ended questions that were the same on both tests.(Appendix II A) Both tests were scored using the same rubric(Appendix II B), and each question could earn a maximum score of three points. The maximum score a student could reach on the test was 36 points. Appendix III C includes a thorough description of how points were awarded on the post-test for each test item.

A pre-test was used to determine students prior knowledge on the themes in genetics. It also assessed gaps in their knowledge and misconceptions they had before the unit began. Out of the seventy parental/student consent forms received, the data analysis included sixty-seven students. Two students scores were not used because they left before or during the unit. Another student failed to answer any questions on the pre/post-test, therefore he was omitted from this study.

Questions one, two, three, and seven had the highest pre-test mean(Figure 1). These questions covered chromosome structure, basic concepts of inheritance and punnett squares, and how sex is determined genetically. Questions four, ten, eleven, and twelve displayed the lowest scores on the pre-test. These questions covered the topics of meiosis, protein

synthesis and information transfer, and polygenetic

inheritance. When looking at the distribution of scores on the

pre-test, there were more students that earned a zero on

questions ten through twelve in comparison to the other

questions(Figure 2). There were many less zero's earned on

questions one through four.
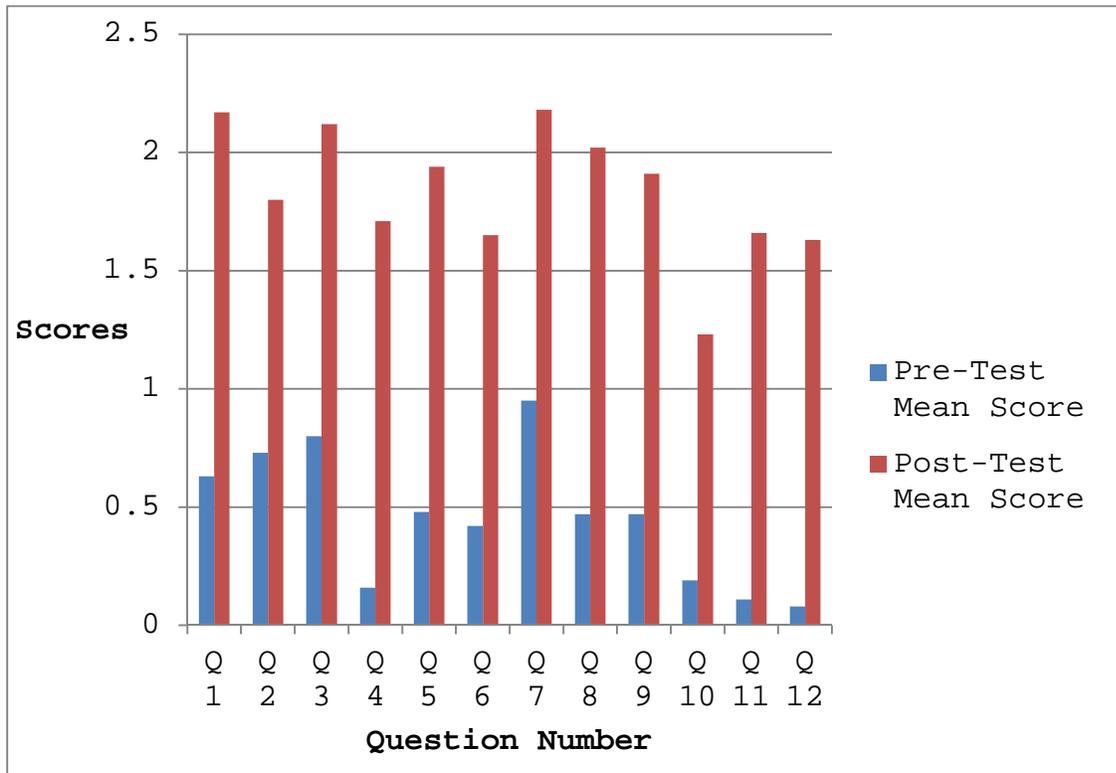
Figure 1: Comparison of the Mean Pre/Post-tests scores per
Question. For interpretation of the references to color in
this and all other figures, the reader is referred to the
electronic version of this thesis.
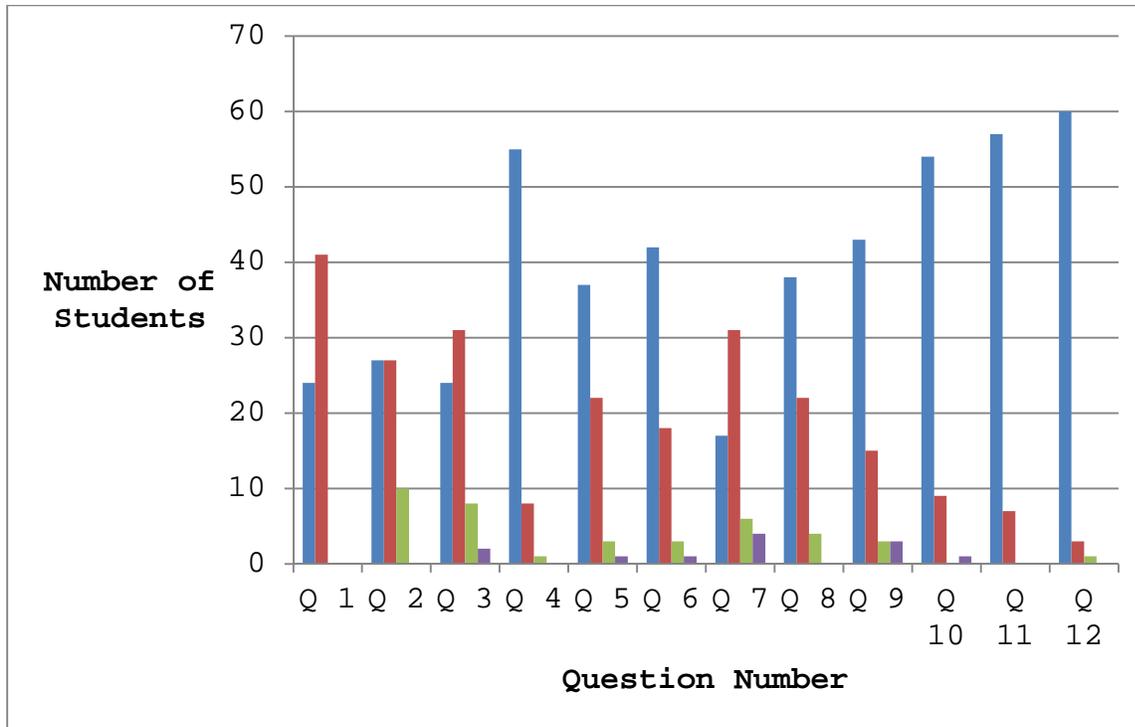
Figure 2: Distribution of the number of students with each score per question on the pre-test. Number of students tested (N) equals sixty-seven. The scores per question ranged from a minimum of zero to a maximum of three points. The blue column indicates the number of scores of zero, the red column indicates the number of scores of one, the green column indicates the number of scores of two, and the purple column indicates the number of scores of three.

According to the post-test scores, the students scored the highest on questions one, three, seven, and eight(Figure 1). The topics covered in those questions were homologous chromosome, basic mendelian inheritance, sex determination, and mutations. The questions the students earned the most high scores of three's were questions three, seven, eight, and nine(Figure 3). The topics covered in those questions are basic mendelian inheritance, sex determination, mutations, and genetic disorders.
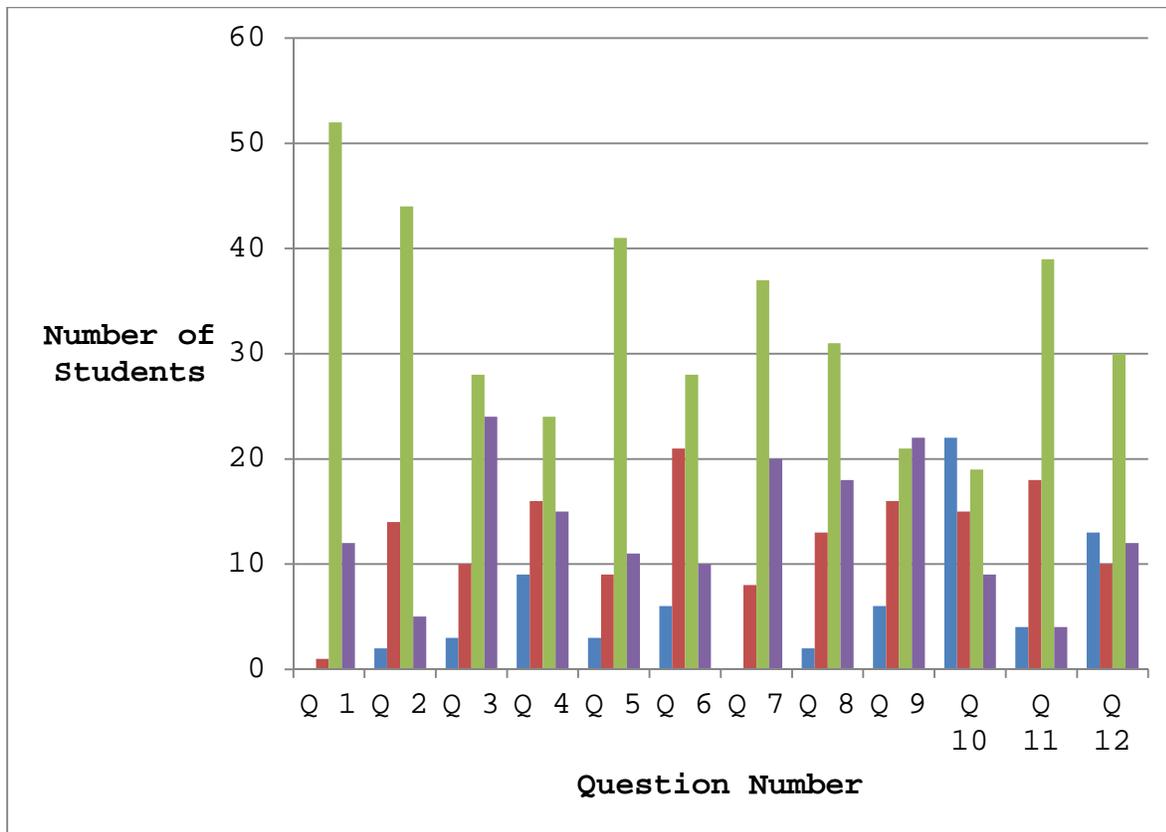
Figure 3: Distribution of the number of students with each score per question on the post-test. Number of students tested (N) equals sixty-seven. The scores per question can range from a minimum of zero to a maximum of three points. The blue column indicates the number of scores of zero, the red column indicates the number of scores of one, the green column indicates the number of scores of two, and the purple column indicates the number of scores of three.

According to the post-test scores, the students scored the lowest on questions six, ten, eleven, and twelve(Figure 1). The topics covered in those questions are DNA structure, polygenetic inheritance, and protein synthesis. The questions the students earned the most low scores of zero's were questions four, ten, and twelve(Figure 3). The topics covered

in those questions are meiosis, polygenetic inheritance, and protein synthesis.

A paired t-test was used as a statistical measure to compare the pre/post-test scores(Table 2). The t-value was calculated using the t-test function in the program Microsoft Excel. The number of students or N value was 68. The p-value for every question of the pre/post-test was below 0.05 for all twelve questions. That means that the pre/post-test data are statistically significantly different and the increase in scores on the post-test was not due to chance, but due to learning that took place using activities in the unit.

Table 2: Mean scores of the pre/post-tests, t-values and statistical significance for the genetics unit assessment.

Question Number	Pre-Test Mean Score	Post-Test Mean Score	t value	Statistically Significant P<.05
Q 1	0.63	2.17	1.85E-26	yes
Q 2	0.73	1.8	3.18E-17	yes
Q 3	0.8	2.12	9.72E-18	yes
Q 4	0.16	1.71	4.00E-16	yes
Q 5	0.48	1.94	3.32E-19	yes
Q 6	0.42	1.65	1.22E-14	yes
Q 7	0.95	2.18	6.83E-17	yes
Q 8	0.47	2.02	3.21E-22	yes
Q 9	0.47	1.91	2.50E-17	yes
Q 10	0.19	1.23	6.57E-10	yes
Q 11	0.11	1.66	1.85E-25	yes
Q 12	0.08	1.63	4.77E-19	yes

On question one of the post-test, the students scored an average of 2.17 out of three points(Table 2). This question asked the students to draw a homologous chromosome with heterozygous alleles. Most students were able to draw a pair of homologous chromosomes, although some students identified heterozygous alleles on the chromosomes. Only a few students showed a misconception by including homozygous alleles on the chromosomes instead of heterozygous. An example of the improvement was demonstrated by one student that could only draw a picture of one chromosome without alleles on the pre-test, but improved on the post-test by drawing a homologous pair of chromosomes with an "A" allele on one and an "a" on the other.

On question two of the post-test, the students scored an average of 1.8 out of three points(Table 2). The question asked the students to complete a given cross and determine which trait was dominant or recessive. Very few students could draw the chromosomes post-instruction, even though they just completed this in the previous question. An example of improvement was demonstrated when a students could only answer that "the dominant trait was the purple stem" on the pre-test and could not set up a punnett square to determine the probably phenotypes and genotypes of the offspring. On the post-test,

the same student said, "purple was the dominant allele, and the outcome would be PP - purple, Pp - purple, Pp - purple, and pp - green", which showed the student understood the cross and how to determine the outcome.

On question three of the post-test, students earned an average score of 2.12 out of three points(Table 2). The students were to determine the genotypes of the parent cross when given a genotype of an offspring. Most students could at least give one possible pair for two points. A student demonstrated improvement in this question by giving one correct mating pair on the pre-test, "Ww X wW", whereas on the post-test the same student wrote down two correct mating pairs, "Ww X ww" and "Ww X Ww", along with completed punnett squares.

On question four of the post-test, students earned an average score of 1.71 out of three points(Table 2). Students were to explain why gametes are genetically different from one another. Most students could show understanding of some part of meiosis, but could not articulate that there is a reduction in chromosome number and that genetic recombination occurring during meiosis. A demonstration of student improvement was shown through a student on the pre-test that answered, "the egg and sperm cells have different traits, then the gametes resulting will be genetically different". The answer was vague

and it showed the misconception that gametes are different from egg and sperm cells. On the post-test the same student answered, "gametes that are genetically different would be produced during meiosis when the chromosomes separate twice to produce haploid cells with only half the amount of chromosomes in a normal body cell", which showed a complete understanding of meiosis.

On question five of the post-test, students earned an average score of 1.94 out of three points(Table 2). Students explained what a co-dominant trait was and how blood type was an example of a co-dominant trait. Most students could explain what a co-dominant trait was, but only a few students could apply it to the A and B alleles of blood typing. An example of improvement was demonstrated when one student on the pre-test answered, "that one thing is close to being dominant, but not close enough". The same student answered on the post-test, "when both alleles are dominant and both alleles for A and B blood type are dominant", which showed an understanding of co-dominance.

On question six of the post-test, students earned an average score of 1.65 out of three points(Table 2). The students were to describe the role of DNA in producing protein. Some student answers showed that they still held on to the idea

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that DNA is the "brain" or "control center", but could not apply it to fact that it contains the information to make proteins. An example of improvement was demonstrated when one student answered on the pre-test, "DNA will tell the cells how to make each characteristic of you". The same student on the post-test answered, "DNA separates, allowing RNA to be made from the DNA, and the RNA travels to the ribosomes and each amino acid matches up with a specific RNA codon".

On question seven of the post-test, students earned an average score of 2.18 out of three points(Table 2). The students were to describe how sex is determined genetically and explain the probability of males verses females. Most of the students scored two to three points of this question and showed accurate knowledge of the genetics of sex determination. An example of improvement was demonstrated when one student on the pre-test answered, "the genes, X and Y chromosomes because they determine everything". The same student showed growth on the post-test when he/she answered, "sex is determined by the X and Y chromosomes. It is always a 50% chance it will be a male or female. The mothers egg carries and X chromosomes and the dad carries an X or Y chromosome."

On question eight of the post-test, students earned an average score of 2.02 out of three points(Table 2). Students

were to define a mutation and gave reasons as to why mutations affect gene function. Most students could identify a mutation and described the fact that it affected gene expression. Only a few could describe how it affected the gene expression through altering protein structure. An example of student improvement was demonstrated when one student on the pre-test answered, "mutation is a genetic defect, and they can completely change how the gene looks and works". The same student on the post-test answered, "mutations are spontaneous changes in your DNA, they can change the protein produced".

On question nine of the post-test, students earned an average score of 1.91 out of three points(Table 2). Students were to link mutations to genetic disorders and explain how a genetic disorder could result in an offspring when neither parent exhibited the disease. Most students could explain how a mutation led to a genetic disorder and identified that the parent generation were heterozygous/carriers of the deleterious recessive allele. A student demonstrated improvement when they answered on the pre-test, "the parents have the gene, but it is dormant, then the child is born with it and it reacts". The same student on the post-test revealed that, "If the child gets the disease it can be from both parents carrying the recessive".

On question ten of the post-test, students earned an average score of 1.23 out of three points(Table 2). Students were to define a polygenetic trait and explain how it differed from normal dominant and recessive inheritance. Most students could identify a polygenetic trait, but did not explain why it resulted in so many phenotypic outcomes. An example of improvement was demonstrated by one student that on the pre-test answered, "because there are many factors and are both inherited by the child". The same student answered on the post-test, "eye color or hair color are polygenetic because more than one gene describes them, there are many combinations that are possible for the trait".

In question eleven, students earned an average score of 1.66 out of three points(Table 2). Students were to describe which part of DNA contained the information and explain how that information differed from person to person to result in different traits. Students could identify that DNA was different in different people, but they were having trouble recognizing which structure, the nitrogen bases, were different. An example of improvement was demonstrated by one student that on the pre-test answered, "DNA is a double helix". The same student on the post-test answered, "DNA is a double helix that has four bases: A, T, C, G. These bases match up

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with mRNA bases: U, A, C, G. The information is then translated into proteins that make the characteristics".

In question twelve, students earned an average score of 1.63 out of three points.(Table 2) Students were to determine how information is transferred, and through which molecules, from DNA to completed protein. Students could relay part of the information flow process, but were not complete with their responses. An example of improvement was demonstrated when a student on the pre-test answered, "DNA carries molecules that carry information to make a protein". The same student on the post-test answered, "DNA is split by enzymes into mRNA. mRNA then enters the ribosome where it decodes the mRNA. The mRNA then pairs with tRNA to create amino acids. When these amino acids pair up then they become protein".

DISCUSSION

The purpose of the research conducted in this study was to determine if there was a correlation between teaching methods and student achievement in a unit of genetics. The teaching methods included using hands-on models, problem solving, and inquiry-based activities. Student achievement was determined by the score comparison on a open ended pre/post-test.

The data collected supported the hypothesis that these methods correlated with improved student achievement. The students scored higher on the post-test on all twelve questions in comparison to the pre-test. The paired t-test analysis showed that the students' post-test scores were significantly different than their pre-test scores. Thus, the students demonstrated an increase in their knowledge of this material due to the activities completed in this unit.

Overall, the new activities that were integrated into the genetics unit supported learning as hypothesized. The improvement on the post-test was attributed to the knowledge the students gained from completing these activities as part of instruction. Not only did the students learn the science content within the topics of genetics, but they enjoyed the activities as well. The activities involved active experiences and working in groups, all of which students enjoy. The

students maintained positive attitudes throughout these activities, which also led to an increase in learning and knowledge(Gibson and Chase, 2002).

Inquiry-based methods were integrated into this unit through the *Fast Plant® activity*. This activity was a success because the students used science skills to see inheritance patterns of the characteristic of stem color in Fast Plants®. This is a change from previous lessons because the students could actually observe the phenotypes of the offspring instead of learning about crosses through drawing punnett squares. Thus, students were able to correctly determine outcomes of crosses on the post-test due to the knowledge they gained from this activity. Also, the students demonstrated high scores on the pre-test involving the questions that addressed mendelian genetics and inheritance patterns. The students had constructed punnett squares and learned how they relate to inheritance in middle school, which led to an increase in their pre-test scores.

Using inquiry-based methods enriched the lessons by having the students complete the scientific process from beginning to end(Chiappetta and Adams, 2004). The students created a hypothesis, gathered data, and made conclusions about the inheritance of stem color through two generations of plants.

From this activity, students observed the outcomes of

inheritance while learning about the law of dominance as well.

The students concluded that purple stems were dominant over

green stems by counting each trait for three generations.

Using inquiry-based methods not only reinforced the knowledge

of inheritance but also were completed in a way that the

students were actively engaged and enjoyed(Keys and Bryan,

2001).

Hands-on models were used in both the *protein synthesis*

and meiosis model activities. Student growth on the post-test

in these two difficult content areas confirmed that using

hands-on models led to an increase in student comprehension in

the areas of protein synthesis and meiosis. These hands-on

activities promoted student learning because the students could

visualize every step of each process by moving the models

kinesthetically with their hands(Barnhart and Farrar, 2011).

However, the students did not score as high on questions

concerning meiosis and protein synthesis in comparison to other

questions. This could be attributed to the difficulty of the

concepts(Harrell, 2001). Protein synthesis and meiosis are

both complex processes with many steps that can be difficult

for students to master even with the help of model activities.

Also, the students had little previous knowledge on these

topics which was demonstrated by their low pre-test scores. In
order to promote a long lasting knowledge of protein synthesis
and meiosis, students need to be exposed to both of these
processes repeatedly in order to gain a complete understanding
of how they work. Neither process can be mastered by a single
exposure or learning experience.

The *Sponge Bob, SeaWorld dihybrid cross, "Super" clam, and*
Blood Type Murder Mystery activities incorporated new forms of
problem solving into the genetics unit. The students were
engaged in these activities because the content was familiar
and they found it more interesting in comparison to the type of
problems that were used in the past(Crawford, 2000). The
achievement shown on the post-test in the content areas of
inheritance patterns, co-dominance, and sex-determination
supported the use of these activities in the classroom. The
pre-test scores were higher in these areas in comparison to
others due to the fact that the students had practiced solving
genetics problems using punnett squares in middle school.

Problem solving was shown to be a successful strategy in
teaching genetics because the students showed a deep
understanding of inheritance on the post-test(White, Bolker,
Koolar, Ma, Maw, and Yu, 2007). The students not only
determined the genotypes of the offspring from the parents on

the post-test, but also had to determine the genotypes of the parents when given the offspring genotype. Answering this type of question demonstrated a higher level of critical thinking skills by the students. Also, a wide variety of genetic problems were used in this unit, where students demonstrated an understanding of several different inheritance patterns on the post-test.

The polygenetic inheritance problem solving activity that was designed for this unit was omitted due to time constraints. The result was that the students scored the lowest on the question that addressed polygenetics. The students scores probably would have increased if the activity was completed in class. The only way students had access to the idea of polygenetics was through lecture and notes. Their low scores supported the fact that lecture and notes were not as effective in improving student knowledge as problem solving activities. Next year, the polygenetic inheritance activity will definitely be used, and students will be assessed to show improvement in that content area.

In conclusion, the activities used in the genetics unit supported the growth of students' knowledge and achievement as demonstrated by the assessments described in this paper. These activities will be used again in future classes to enhance the

genetics unit. After analyzing the low scores on the post-test, the polygenetic inheritance activity will be incorporated into the lesson plans for next year. Also, an analysis is planned of these students' performance on the Michigan Merit Exam this upcoming school year. It will be interesting to see how they score on the genetics objectives post instruction in comparison to previous groups of students. In observing the success of this unit, a further, ongoing evaluation of the other units in biology will be completed looking for other content areas to incorporate inquiry-based, hands-on, and problem solving methods.

APPENDICES

APPENDIX I

Parent Consent Form and State Objectives

Appendix I A: Parental Consent Form

PARENTAL CONSENT AND STUDENT ASSENT FORM

Dear Students and Parents/Guardians:

I would like to take this opportunity to welcome you back to school and invite you to participate in a research project, Using Hands-on Models, Problem Solving, and Inquiry Based Activities to Teach Genetics, that I will conduct as part of Biology class this semester. My name is Mrs. Stephanie Hoppe. I am your biology teacher this semester and I am also a master's degree student at Michigan State University. Researchers are required to provide a consent form like this to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

What is the purpose of this research? I have been working on effective ways to teach Genetics, and I plan to study the results of this teaching approach on student comprehension and retention of the material. The results of this research will contribute to teachers' understandings about the best way to teach basic genetics topics. Completion of this research project will also help me to earn my master's degree in Michigan State University's College of Natural Science.

What will students do? You will participate in the instructional unit on Genetics. You will complete the usual assignments, laboratory experiments and activities, computer simulations, class demonstrations, and pre-tests/posttests just as you do for any other unit of instruction. There are no unique research activities – participation in this study will not increase or decrease the amount of work that students do. I will simply make copies of students' work for my research purposes. This project will continue from September 2012 through June 2013. I am asking for permission from both students and parents/guardians (one parent/guardian is sufficient) to use copies of student work for my research purposes. This project will continue from September 2012 through June 2013.

What are the potential benefits? My reason for doing this research is to learn more about improving the quality of

science instruction. I won't know about the effectiveness of my teaching methods until I analyze my research results. If the results are positive, I can apply the same teaching methods to other science topics taught in this course, and you will benefit by better learning and remembering of course content. I will report the results in my master's thesis so that other teachers and their students can benefit from my research.

What are the potential risks? There are no foreseeable risks associated with completing course assignments, laboratory experiments and activities, computer simulations, class demonstrations, and pre-tests/posttests. In fact, completing course work should be very beneficial to students. Another person will store the consent forms (where you say "yes" or "no") in a locked file cabinet that will not be opened until after I have assigned the grades for this unit of instruction. That way I will not know who agrees to participate in the research until after grades are issued. In the meantime, I will save all of your written work. Later I will analyze the written work only for students who have agreed to participate in the study and whose parents/guardians have consented.

How will privacy and confidentiality be protected? Information about you will be protected to the maximum extent allowable by law. Students' names will not be reported in my master's thesis or in any other dissemination of the results of this research. Instead, the data will consist of class averages and samples of student work that do not include names. After I analyze the data to determine class averages and choose samples of student work for presentation in the thesis, I will destroy the copies of student's original assignments, tests, etc. The only people who will have access to the data are me, my thesis committee at MSU, and the Institutional Review Board at MSU. The data will be stored on password-protected computers (during the study) and in a locked file cabinet in Dr. Heidemann's locked office at MSU (after the study) for at least three years after the completion of the study.

What are your rights to participate, say no, or withdraw? Participation in this research is completely voluntary. You have the right to say "no". You may change your mind at any time and withdraw. If either the student or parent/guardian

requests to withdraw, the student's information will not be used in this study. There are no penalties for saying "no" or choosing to withdraw.

Who can you contact with questions and concerns? If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher Mrs. Stephanie Hoppe: shoppe@grasslakeschools.com; 517-522-5570,and /or Dr. Merle Heidemann: 354 Farm Lane #118, Michigan State University, East Lansing, MI 48824; heidema2@msu.edu; 517-884-3468.

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

How should I submit this consent form? If you agree to participate in this study, please complete the attached form. Both the student and parent/guardian must sign the form. Return the form to Mrs. Danielle Doctor by September 14, 2012.

Name of science course:
Teacher:
School:

Parents/guardians should complete this following consent information:

I voluntarily agree to have
_____ participate in
this study.
(print student name)

Please check all that apply:

Data:

_____ I give Mrs. Hoppe permission to use data generated
from my child's work in this class for her thesis project. All
data from my child shall remain confidential.

_____ I do not wish to have my child's work used in this
thesis project. I acknowledge that my child's work will be
graded in the same manner regardless of their participation in
this research.

Photography, audiotaping, or videotaping:

_____ I give Mrs. Hoppe permission to use photos,
audiotapes, or videotapes of my child in the class room doing
work related to this thesis project. I understand that my
child will not be identified.

_____ I do not wish to have my child's images used at any
time during this thesis project.

Signatures:

_____
    (Parent/Guardian Signature)   (Date)

I voluntarily agree to participate in this thesis project.

_____
(Student Signature)   (Date)

Appendix I B: Michigan High School Content/Objectives concerning genetics taken from the Michigan Department of Education Website.

B4.1 Genetics and Inherited Traits

Hereditary information is contained in genes, located in the chromosomes of each cell. Cells contain many thousands of different genes. One or many genes can determine an inherited trait of an individual, and a single gene can influence more than one trait. Before a cell divides, this genetic information must be copied and apportioned evenly into the daughter cells.

B4.1A Draw and label a homologous chromosome pair with heterozygous alleles highlighting a particular gene location.

B4.1B Explain that the information passed from parents to offspring is transmitted by means of genes that are coded in DNA molecules. These genes contain the information for the production of proteins.

B4.1c Differentiate between dominant, recessive, codominant, polygenic, and sex-linked traits.

B4.1d Explain the genetic basis for Mendel's laws of segregation and independent assortment.

B4.1e Determine the genotype and phenotype of monohybrid crosses using a Punnett Square.

B4.2 DNA

The genetic information encoded in DNA molecules provides instructions for assembling protein molecules. Genes are segments of DNA molecules. Inserting, deleting, or substituting DNA segments can alter genes. An altered gene may be passed on to every cell that develops from it. The resulting features may help, harm, or have little or no effect on the offspring's success in its environment.

B4.2A Show that when mutations occur in sex cells, they can be passed on to offspring (inherited mutations), but if they occur in other cells, they can be passed on to descendant cells only (non-inherited mutations).

B4.2B Recognize that every species has its own characteristic DNA sequence.

B4.2C Describe the structure and function of DNA.

B4.2D Predict the consequences that changes in the DNA composition of particular genes may have on an organism (e.g., sickle cell anemia, other).

B4.2x DNA, RNA, and Protein Synthesis

Protein synthesis begins with the information in a sequence of DNA bases being copied onto messenger RNA. This molecule moves from the nucleus to the ribosome in the cytoplasm where it is "read." Transfer RNA brings amino acids to the ribosome, where they are connected in the correct sequence to form a specific protein.

B4.2f Demonstrate how the genetic information in DNA molecules provides instructions for assembling protein molecules and that this is virtually the same mechanism for all life forms.

B4.2g Describe the processes of replication, transcription, and translation and how they relate to each other in molecular biology.

B4.2h Recognize that genetic engineering techniques provide great potential and responsibilities.

B4.r2i Explain how recombinant DNA technology allows scientists to analyze the structure and function of genes. *(recommended)*

B4.3 Cell Division — Mitosis and Meiosis

Sorting and recombination of genes in sexual reproduction results in a great variety of possible gene combinations from the offspring of any two parents.

B4.3A Compare and contrast the processes of cell division (mitosis and meiosis), particularly as those processes relate to production of new cells and to passing on genetic information between generations.

B4.3B Explain why only mutations occurring in gametes (sex cells) can be passed on to offspring.

B4.3C Explain how it might be possible to identify genetic defects from just a karyotype of a few cells.

B4.3d Explain that the sorting and recombination of genes in sexual reproduction result in a great variety of possible gene combinations from the offspring of two parents.

B4.3e Recognize that genetic variation can occur from such processes as crossing over, jumping genes, and deletion and duplication of genes.

B4.3f Predict how mutations may be transferred to progeny.

B4.3g Explain that cellular differentiation results from gene expression and/or environmental influence (e.g., metamorphosis, nutrition).

B4.4x Genetic Variation

Genetic variation is essential to biodiversity and the stability of a population. Genetic variation is ensured by the formation of gametes and their combination to form a zygote. Opportunities for genetic variation also occur during cell division when chromosomes exchange genetic material causing permanent changes in the DNA sequences of the chromosomes. Random mutations in DNA structure caused by the environment are another source of genetic variation.

B4.4a Describe how inserting, deleting, or substituting DNA segments can alter a gene. Recognize that an altered gene may be passed on to every cell that develops from it and that the resulting features may help, harm, or have little or no effect on the offspring's success in its environment.

B4.4b Explain that gene mutation in a cell can result in uncontrolled cell division called cancer. Also know that exposure of cells to certain chemicals and radiation increases mutations and thus increases the chance of cancer.

B4.4c Explain how mutations in the DNA sequence of a gene may be silent or result in phenotypic change in an organism and in its offspring.

APPENDIX II

Pre/Post-Tests, Rubrics, and Rubric Explanations

Appendix II A: Pre/Post-test

Genetics Unit Pre/Post-test

1. Draw and label a pair of homologous chromosomes with
heterozygous alleles.

2. Plants have genetic information that passes from one
generation to the next just like people do. When observing
fast plant characteristics, such as stem color, purple stems
are dominant over green stems. 1. What does dominant mean in
terms of stem color? 2. If two heterozygous parents for stem
color are crossed (Pp X Pp), what will be the proportion of
purple and green stems in offspring? 3. Draw a picture(like
you did in Q #1) showing the chromosomes associated with this
characteristic in the gametes(egg and sperm).

3. Widow's peak is a characteristic where the hairline dips in
the center instead of a straight hair line. Widow's Peak is a
single gene trait where there are two versions of the trait "W"
for widow's peak and "w" for absence of widow's peak. A family
has three children, all of which do not have widow's peaks
(ww). What would be a possible combination of genotypes for
mom and dad to produce children without widow's
peaks(ww)?(Include as many combinations as possible)

4. Meiosis is the process of separating pairs of chromosomes
to make gametes(egg and sperm). Describe one way the process
of meiosis results in gametes that are genetically different.

5. AB blood is one of the four blood types. People that have AB blood have an "A" gene and a "B" gene where the two genes are co-dominant. 1. What is co-dominance 2. What does it mean for blood type to be a co-dominant trait?

6. What is the role of DNA in producing the building blocks of the body which are proteins?

7. How is sex determined genetically? What is the chance that an offspring will be male or female? Explain.

8. Some organisms, such as clams, have mutations in their DNA that allow them to be resistant against disease. 1. What is a mutation? 2. How can mutations affect how a gene functions?

9. What is the connection between a human genetic disorder such as sickle cell anemia and a mutation? How is a genetic disease inherited by a child when neither parent shows symptoms of the disease?

10. What does it mean for a characteristic that has many different forms such as eye or hair color, to be polygenetic? Explain why polygenetic inheritance does not follow the rules of simple dominant/recessive inheritance?

11. DNA is genetic information. 1. Describe the structure of DNA focusing on the part that carries the information. 2. What happens to the information in DNA that allows a characteristic such as eye or hair color to change in different people?

12. Hemoglobin is a protein in red blood cells that carries oxygen to your body cells. I want you to think about how the information in DNA flows through the cell to form hemoglobin. Describe what part of the following molecules carries the information/code to make a protein like hemoglobin: DNA, mRNA, and protein?

Appendix II B: Pre/Post-test Assessment Rubric

Table 3: Genetics Unit Assessment Rubric

Question	Basic (1pt)	Developing (2pts)	Mastery (3pts)
1	Drawing somewhat represents a chromosome	Correct chromosome structure, alleles incorrect	Great drawing of homologous chromosome with correct allele location
2	Some knowledge of inheritance exhibited	Correct offspring, gametes incorrect	Correct offspring genotypes and phenotypes, correct gametes
3	Some knowledge of inheritance exhibited	One correct mating pair.	More than one correct mating pair.
4	Some knowledge of meiosis exhibited	Shows understanding that genetic recombination or idea that chromosome number was decreased	Shows understanding that genetic recombination and decreased chromosome number occurred
5	Shows at least some knowledge of co-dominance	Describe in detail what co-dominance is.	Can identify why AB blood is co-dominant, and what co-dominance is.
6	Shows some knowledge of protein synthesis	Accurately describes transcription or translation.	Accurately describes transcription and translation when making protein from DNA.
7	Shows some knowledge of how gender is inherited	Exhibits accurate knowledge of how X and Y are inherited, or that they are inherited at a 50:50 ratio.	Exhibits knowledge of how X and Y chromosomes are inherited, and explains why it is always 50:50.

Table 3: Cont'd

8	Displays some knowledge of mutation	Shows detailed knowledge of what a mutation is	Shows the knowledge that mutations affect genes, which affect proteins produced.
9	Displays some knowledge of genetic disorder	Connects genetic disease with problems with genes	Can identify the parents genotype as heterozygous if both parents are not showing signs of the disease.
10	Displays some knowledge of polygenetic inheritance	States that it is inherited by many genes	States that it is inherited by many genes instead of a single gene trait
11	Has some knowledge of DNA structure	Describes DNA Structure in depth	Describes DNA Structure and identifies that changes in the bases will cause a change in the characteristic
12.	Displays some knowledge of DNA as information	Can describe where in the information is located in one molecule:DNA, mRNA, or amino acids.	Can describe where the information is located in all molecules involved in protein synthesis: DNA, mRNA, and amino acids

Appendix II C: Thorough explanation of rubric scores

Question One:

I gave the students one point if they could draw a chromosome with joined sister chromatids. I gave the students two points if they could draw a pair of chromosomes. The students had to include heterozygous alleles on the chromosomes to earn all three points.

Question Two:

A student received one point if they could determine which trait was dominant or write down the correct cross. A student received two points if they could do both. The students received three points if they could draw the parents chromosome from the cross.

Question Three:

Students earned two points if they had one possible correct pair. Students earned three points if they had more than one possible correct pair.

Question Four:

The students earned a score of one point if they could demonstrate any knowledge of meiosis. They students earned a score of two points if they said that the cells divide twice

and chromosome number decreases or if they said that genetic recombination occurs during the process. The students earned three points if they said that the chromosome number decreases and genetic recombination occurs.

Question Five:

The students earned one point if they could demonstrate they understood what a co-dominant trait was. The students earned two points if they could explain how blood typing is co-dominant. The students earned three points if they could explain how blood typing is co-dominant and explain what a co-dominant trait is.

Question Six:

The students earned one point if they displayed some knowledge of protein synthesis. The students earned two points if they could accurately describe transcription or translation. The students earned all three points if they could accurately describe both processes.

Question Seven:

The students earned one point if they stated it is a 50:50 ratio of males to females. They received two points if they had the ratio correct and some part of the genotypes correct.

The students received three points if they had the genotypes
and ratios accurate.

Question Eight:

Students earned one point by displaying some knowledge of
mutation. Students earned two points if students linked a
mutation with altered protein formation. Students earned all
three points if they could link together a change in DNA code
of a gene to a mutation and change in protein structure.

Question Nine:

The students earned one point if they could link the mutation
to genetic disorder by explaining a basic understand of altered
DNA. The students earned two points if they could explain that
a genetic disorder is on the recessive allele and the parents
must be carriers for an offspring to get the disease. The
students earned three points if they made the connecting
between mutation/altered DNA and genetic disorder as well as
explaining the parents are carriers and the disease was
recessive.

Question Ten:

The students earned one point if they could show any
understanding of polygenetic inheritance. The students earned
two points if they could explain that it is a trait that is

expressed by many genes. The students earned three points if
they could explain that it is expressed by many genes and
discuss why that results in so many different phenotype
combinations.

Question Eleven:

Students received one point if they could give a basic idea of
how DNA is information. Students received two points if they
could identify that the nitrogen bases on the DNA are the part
that carries the information to make the traits. Students
received three points if they could identify that DNA contains
nitrogen bases to carry information, and people have different
traits based on their own unique sequences of bases.

Question Twelve:

Students earned one point if they could display some knowledge
of DNA as information to make proteins. Students earned two
points if they could describe how the information if
transferred into mRNA or amino acids. Students earned three
points if they could describe how DNA is transcribed into mRNA,
which is translated into amino acids, and then linked together
by peptide bonds to build a protein.

APPENDIX III

Activities and Labs

Appendix III A: Fast Plant® Guided Inquiry Lab

Genetics Investigation: Purple vs. Green Stems

     Have you ever seen a plant with purple stems? Stem color is actually a single gene trait in Brassica plants. In this investigation, you are going to plant seeds to observe the traits of three generations of plants. To complete the activity in a timely manner we are going to grow the seeds for the parental (p), first generation (f1), and second generation (f2) all at once. You are going to be able to determine which trait is dominant by the end of this activity and determine actual phenotypic ratios for the first and second generation.

Problems: Will all the offspring be hairy? hairless? intermediate?

Half offspring hairy/half hairless?   some other fraction? EXPLAIN YOUR ANSWER

Hypothesis: Using a punnett square, what is the expected ratios of dominant and recessive phenotypes for the f1 and f2 is the parents are true-breeding/ homozygous for each trait.

Materials:

- 3 of each parent, f1, f2 seeds per group
- one quad
- four wicks
- tape to label chambers
- watering system
- Plant Light

Procedure:

1. Gather materials

2. Fill dirt 3/4 way to the top of three chambers of the quad

3. plant 3 seeds of the hairy parent in one chamber and label

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4. plant 3 seeds of the hairless parents in one chamber and label

5. plant 3 seeds of the f1 generation in one chamber and label

6. plant 3 seeds of the f2 generation in one chamber and label

7. Fill all chambers up the top of the quad with dirt and water top with pipette. Place on watering system.

Data: Draw a table tallying the stem color for the three generations.

Discussion Questions:

1. Which trait is dominant and which is recessive? How do you know?

2. What is the phenotypic ratio of green/purple stems in the first generation? Second generation?

3. Now you know which trait is dominant show the punnett square for the first and second generations.

First generation cross   _____   X   _____

Draw the Punnett Square below:

Second generation cross   _____   X   _____

Draw the Punnett Square below:

Appendix III B: Meiosis Models Activity

Modeling Meiosis Activity

Have you ever wondered, "why do I look so much different from my brothers and/or sisters?". The way that gametes (egg and sperm) cells are formed is much different than the process of typical cell division. It involves a process called meiosis. In this activity, you are going to use models to simulate the process the chromosomes go through during egg and sperm formation to make them genetically different.

Problem: How does the process of meiosis result in gametes (egg and sperm) that are genetically different when they are coming from the same person?

Directions: You are going to use foam chromosomes to model meiosis to see how the chromosomes move to form genetically different cells. You will use 3 pairs of foam models, but remember that humans actually have 23 pairs. You will be drawing pictures, answering process questions during the activity, and completing analysis questions at the end.

Meiosis I

1. The chromosomes are copied before meiosis begins. Connect the pairs of chromosomes using the velcro centromeres. Using color to distinguish between mom and dad's chromosomes draw a picture of the cells in the testes and ovaries before meiosis has begun and after the chromosomes have copied themselves into sister chromatids.

Draw the chromosome arrangement in the following stages:

Before Meiosis   After Replication

Prophase I - Telophase I: During prophase I, the chromosomes
form homologous pairs or tetrads. Pair up the chromosomes to
show this.   That is where moms' replicated chromosomes and
dad's replicated chromosomes pair up, but are physically not
connected. This is also where crossing over occurs. Line the
chromosomes up in homologous pairs for metaphase I, however the
sister chromatids do not disconnect at this point**. This is the
major difference between meiosis and mitosis.**   Draw the cell
in metaphase I below. During anaphase I The homologous pair
splits, but the sister chromatids stay together. Then,
Telophase one the chromosomes form two new nuclei. Draw the
cell after the completion of meiosis I.

Draw the chromosome arrangement in the following stages:

Metaphase I   End of Meiosis I

How many cells and how many chromosomes are there in each cell
at the end of meiosis I?

Are the cells genetically the same or different at this point?

How many chromosomes would be in each cell in your cells at
this point?

Meiosis II

Meiosis II is virtually the same process as mitosis. Using
your knowledge of mitosis divide the chromosomes the same way
through the phases and draw the cells accordingly. Hint:
Telophase I looks the same as prophase II.

Draw the chromosome arrangement in the following meiosis
stages:

            Metaphase II   End of Meiosis

How many cells and how many chromosomes are in each cell at the
end of Meiosis II?

How many chromosomes would be in a human egg and sperm cell at
this point?

1.   If there are only three chromosomes in an organism's cell, like in this simulation, how many possible combinations of chromosomes would there be in their gametes?

2.   How many possible combinations are there in human gamete formation?

3.   How does the process of meiosis form cells that are genetically different?

4.   How is meiosis different from mitosis?

5.   Females only produce one egg a month, what about the other three cells produced?

Genotype to Phenotype Activity:

Directions: You are going to take the gametes you formed and cross them with other gametes to form offspring. As a class we are going to choose an organism that we will simulate the mating. You will also choose what traits that the alleles will represents.

Model Organism and traits/alleles:

What are the genotypes of your four gametes?

Gamete #1   Gamete #2   Gamete #3   Gamete #4

Genotypes:

 Mate your organism by combining the chromosomes from each of
your gametes with the table in your row. The table from the
right will represent female gametes and the table to your left
will be male gametes. At this point you have four offspring
combinations. Record the genotypes and phenotypes of the
offspring.

Offspring#1   Offspring #2   Offspring #3   Offspring #4

Genotypes:

Phenotypes:

Circle one of your offspring.   Unfortunately, only this
offspring can actually form because during meiosis in females
only one egg is produced and the three other cells are polar
bodies and will not result in offspring. Draw your offspring
below:

Appendix III C: Protein Synthesis Models Activity

Protein Synthesis Model Activity

Problem: DNA is the blue print to make your body structures and proteins are the building blocks, how is the information in the DNA used to make complex proteins?

Directions: The purpose of this activity is to learn the processes of transcription and translation using hands-on models. You will be constructing the mRNA and amino acid sequence from the DNA template the same way your cells do to make proteins. Once you have completed the activity you will do it again in reverse where you will be given amino acids and you will have to find the mRNA and DNA that codes for the given amino acids. You will be answering process questions during this activity and analysis questions at the end.

1. Using a DNA backbone (deoxyribose sugar and phosphate), construct a 9 base DNA strand. Remember you want to start with TAC because it will correspond to the start codon on the mRNA to begin translation later on. Record the bases of the half DNA strand below:

DNA

What is the enzyme that breaks the DNA helix in half to begin either DNA replication or transcription?

TRANSCRIPTION

2. Using the DNA as a template, transcribe the mRNA strand using the models. Again, the mRNA backbone consists of Ribose sugar and phosphate. Record the order of the mRNA bases below.

mRNA

What is the enzyme in the nucleus that makes mRNA from DNA?

Where does transcription occur in the cell?

Where does the mRNA travel to in the cell after transcription?

TRANSLATION

3. Using blank amino acids attached to the tRNA, translate the mRNA code into an amino acid chain. Use the "secret decoder wheel of life" in your textbook to find the amino acids that correspond to the mRNA codons. Below I would like you to record the tRNA anti-codons attached to the amino acids in order that you translated from you mRNA above.

tRNA

Amino Acids

In which organelle does translation occur?

What is the role of tRNA?

What are the different types of proteins that are produced by the cell?

4. Now that you have completed protein synthesis, you will complete the process again in reverse. I want you to build a protein that has three amino acids. Remember it has to start with the start amino acids which is methionine. The next two

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amino acids are the two in your kit that are named, and you can attach these two in any order. Record the sequence of the three amino acids below.

Amino Acid Sequence

5. Using the amino acid sequence above, de-translate the code into the anti-codon on the tRNA and the codon on the mRNA. Also, add on a stop codon to the end of your 9 base mRNA strand to show that was the end of the protein.

tRNA

mRNA

6. Using the mRNA above, de-transcribe the code into the half DNA strand. The DNA should be 12 bases long.

DNA

Analysis Questions:

Describe the process of transcription.

Describe the process of translation.

What would happen to the protein if RNA polymerase substituted the base uracil for cytosine during transcription? What is it called when the code is changed?

How can the sequence of amino acids dictate what type of protein is produced?

Appendix III D: "Super" clam case study activity

Case Study of a "Super" Clam

    Have you ever read on a menu, "Take precaution when eating undercooked shellfish"? Why is that? It partially has to do with a phenomenon known as the red tide which is a harmful algal bloom. It is named for the characteristic red sea that results from the high number of algae in the area and kills many sea creatures. It is caused by a protist called a dinoflaggellate. I wonder how they move? Hmmm. When you eat undercooked shellfish that have been exposed to this protist, it can cause illness in humans, even death. Ouch!!! Luckily, the shellfish industry is careful about not selling organisms that have been exposed to the red tide, but what about the poor clams in the area? When the clams are exposed to the dinoflagellate, it releases a neurotoxin that affects their nervous system, in turn killing the shellfish. But for a select few clams that is not the case. They are resistant to the red tide and not affected by the neurotoxin at all. Scientists have discovered they have a key protein that does not allow the neurotoxin to bind. They are "Super" clams!!! How does that happen? Let's look at a piece of the DNA that codes for the protein channel. Remember that the actual DNA sequence is actually over one thousand base pairs long!

"Normal" Clam Nucleotide Sequence

ACC TAA CTC AGC

"Super" Clam Nucleotide Sequence

ACC TAA CTA AGC

Transcribe and Translate the DNA sequences of the "Normal" and "Super" Clams into mRNA and amino acid sequences.

"Normal" Clam

mRNA

Amino Acids

"Super" Clam

mRNA

Amino Acids

When observing the protein formed from the DNA sequences above, do you see a genetic reason as to why the "Super" Clam is different from the "Normal" Clam? If so, how could the fact that the "Super" Clam is resistant to the red tide have to do with genetics?

What type of mutation is it?

What do you think is going to happen the number of resistant genes in the population? How is the resistant "Super" clam an example of evolution?

Based on research conducted in Evo-Ed and Lyman Briggs College at M.S.U.

Appendix III E: Blood Typing Murder Mystery

Multiple Alleles Investigation: Blood Types

Adapted from: steinkscience.wikispaces.com

1. What is a multiple allele trait?

2. What are the possible alleles for blood groups?

3. What are 4 the possible phenotypes for blood? What are the possible genotypes for each of these phenotypes?

4. What is Co-dominance, and how does this term relate to blood groups?

5. Construct a Punnett Square for the cross between a man with type O blood and a woman with type AB blood.

6. If this man and woman have a baby, what possible blood types could the baby have?

7. What is the probability that the baby will have each of these blood types?

Multiple Alleles Investigation:
        A Bloody Mystery

You are a lawyer for the following:

Mr. Cash died and left all of his money to his two children.
Because of Mr. Cash's prominent role in society, his death made
headlines. Shortly after, a young man named Charlie, who claims
to be Mr. Cash's long lost son arrives and demands his share of
the inheritance. Mr. Cash's two children and their lawyers are
skeptical and refuse this young man the money, so he sues. The
judge orders blood tests for all of the family. Mr. Cash's blood
type, as it appears on his hospital records, is AB. His wife had
blood type A. Mr. Cash's two known children were both type B.
The young man claiming to be a long lost son had blood type O.

Based on the blood tests, prove to the judge whether or not
Charlie could be a child of Mr. Cash. Create a case (1
paragraph) defending your conclusion. Determine the genotypes
for each individual involved, and use at least two Punnett
Squares as evidence.

Appendix III F: Polygenetic Inheritance Activity

Polygenetic Inheritance Lab

Problem: Why are there so many different forms of the characteristics of height, eye color, and hair color?

Background: Polygenic traits are traits that are controlled by more than one gene, i.e. height, weight, hair color, skin color (basically, anything that deals with size, shape and color). This allows for a wide range of physical traits. For example, if height was controlled by one gene A and if AA= 6 feet and aa= 5 feet, then people would be one of two different heights. Since height is controlled by more than one gene, a wide range of heights is possible.

Once the coins have been handed out (six per each group) and the procedures have been reviewed, I will put a class result table on the board, so that the class can collect the data. Each group will record the number of times the following situations occurred when the coins were flipped.   Each coin represents a different gene that height is inherited from.

Procedure:

1.   Each group will carefully flip all six coins on the lab table. I would have one person shake the coins in their hand and have them gently spill onto the table. I would have the other partner record the heads and tails
2.   Record the number of heads and tails that result from the flip in table 1.
3.   Continue to flip the six coins and continue to record the number of heads and tails that result from the flip until table 1 is complete.
4.   Complete table 2 by adding up the number of times the following situations occurred.
o   0 Tails and 6 Heads
o   1 Tail and 5 Heads
o   2 Tails and 4 Heads
o   3 Tails and 3 Heads
o   4 Tails and 2 Heads
o   5 Tails and 1 Head
o   6 Tails and 0 Heads
5.   Record your results from table 2 on the board with the class results.
6.   Record the class results in table 2.

7.   Construct a bar graph from the class data. The number of heads and tails will go on the X axis (the independent variable), while the number of times the situation occurred will go on the Y axis (the dependent variable).
8.   Answer the questions.

Results: Make a table tabulating your coin flips and the coin flips of your group.

Construct a Graph for both your results and the class results.

Discussion Questions:

Remember: Heads are dominant genes. Tails are recessive genes.

1) Do parents give (All or Half) of their genetic material to their children?

Example for the rest of the questions: A man is 5 feet 7 inches tall, has 3 heads (dominant genes) and 3 tails (recessive genes). He will give 3 genes to his child. These 3 genes can be given randomly.

He can give 3 dominant genes and no recessive genes

He can give 2 dominant genes and 1 recessive gene

He can give 1 dominant gene and 2 recessive genes

He can give 0 dominant genes and 3 recessive genes

These are all the possible combinations that he can give his child. The height of the mother will dictate the genes that she

will give to the child. The combination of the mother's genes and the father's genes will decide the height of the child.

2) If a male is 5 feet 9 inches tall, it means that he has 4 dominant genes and 2 recessive. He will only give 3 genes to his child. What are the possible combinations of genes that he can give?

    He can give _____ dominant and _____ recessive

    He can give _____ dominant and _____ recessive

    He can give _____ dominant and _____ recessive

3) The male is 5 feet 7 inches and the female is 5 feet 5 inches. Is it possible for them to give their child the necessary genes so the child can be 5 feet 11 inches tall? Explain your answer. Diagrams are often useful.

4) If 2 parents are 5 feet 7 inches, is it possible to have a child that is 6 feet tall? Explain how this is possible.

5) If the male is 5 feet 5 inches tall and the female is 5 feet 3 inches tall, what is the tallest height that their child could attain? Explain.

6) If the male is 5 feet 7 inches tall and the mother is 5 feet 3 inches tall, what is the shortest height their child could attain? Explain.

7) List 3 other polygenic traits.

8) How are polygenic traits different from traits that only require 2 genes?

9) Why do you think that some children are taller than their parents?

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