CLICKERS IN THE HIGH SCHOOL BIOLOGY CLASSROOM

by

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of the requirements for the degree

of

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ACKNOWLEDGEMENT

To Ben, who never questions and simply gives. To Oliver, who always wanted to stay up just a little longer and “watch me work.” To my parents, who mean it when they say they always have my back. To Amanda, for adventures to come. To Sue and Hailey, for helping me talk pretty. And to the RamFam for truly being a fam.

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ABSTRACT

Students were exposed to handheld response clickers as a means aimed to increase engagement and content retention as well as help with metacognition. Data collection tools included a pre- and post-science engagement survey, pre- and post-unit content surveys, a clicker attitude survey, and a qualitative final student interview. Results showed small to negligible normalized gains in treatment versus non-treatment units of study. Similarly, students' science engagement pre- versus post scores were generally unchanged. The Clicker Attitude Survey and post student interview though, showed that when clickers were used in the classroom, students generally did have a positive opinion of clicker use and were anecdotally more likely to examine their own learning.

INTRODUCTION AND BACKGROUND

Bill Nye very succinctly summed up why I am a teacher when he said, "Science is the best idea humans have ever had. The more people who embrace that idea, the better" (Hernandez, 2013, interview question five). I view my role as a facilitator, leading students on their journey towards embracing science. This is easier said than done for some students who view biology as inconsequential since their plans do not involve higher education or they have already decided that science is not their strength. My drive as an educator, therefore, is to continually seek out new strategies and methods that could increase student engagement and lead to a deeper understanding of science.

The school where I conducted my research is located in Dubuque, Iowa at Dubuque Senior High School. Dubuque is commonly referred to as the "Masterpiece on the Mississippi" because of its location overlooking the banks of the Mississippi River. Dubuque is located just minutes from Illinois and Wisconsin (City of Dubuque Mayor & City Council, 2017). Considering its population of only 58,000, Dubuque has won a wide array of awards such as 2016 first place award for National Diversity, 2015 Second Most Relaxed Small City, and in 2014 Dubuque was named One of the 10 Best American Cities to Work in Technology (City of Dubuque Awards & Recognitions, 2017). With a mascot of a Ram, both faculty and students at Dubuque Senior High School refer to themselves as the ‘RamFam.” The purpose of my capstone research centers around increasing the spark of excitement and achievement in my students. Through a series of fortunate events, I was encouraged to apply for a grant at the last minute and was awarded money towards purchasing classroom response systems (CRS) also known as clickers. Through a bit of research, I discovered what a jewel I had stumbled upon and the potential of clickers to achieve the goal of both engaged active learning and content acquisition. Therefore, my research question for my capstone was, what is the effect of a CRS such as clickers on student engagement and science attitudes in a high school biology classroom?

CONCEPTUAL FRAMEWORK

Meta-analysis studies confirm that active student learning leads to greater comprehension, which is measurable through an increase in grades and overall course performance (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014). Students are actively learning when they are connecting with the material in a dynamic way such as group discussions, problem analysis, or interaction with technology rather than traditional content delivery from the teacher. Also, student engagement, which can be loosely defined as the time and energy students put towards learning activities, has been shown to increase with the implementation of active learning, and is itself a strong predictor of performance and grades (Addison, Wright, & Milner, 2009; Kuh, 2003). Research further indicates that active student learning and engagement can be accomplished together, and technology can be the means to this outcome (Beatty, 2011).

Lecturing is the opposite of active learning, and multiple studies have shown that traditional classrooms where lecturing is the primary means of information distribution, can increase failure rates by as much as 55%. Historically, lecturing has been the standard mode of content delivery since time immemorial (Freeman et. al., 2014). This method also makes the assumption that students can passively absorb the content as well as assimilate it into their existing knowledge structure. Few university level students are capable of developing deep connections and understandings of various topics thoroughly enough in a traditional classroom to be able to apply their knowledge to complex real-world problems (National Research Council [NRC], 2000). Ian D. Beatty (2004), a leader in the area of technology and active learning, postulates that traditional teacher to student learning is still prevalent in education because designing a lecture is a predictable and controlled experience for the teacher. Active learning can feel more like steering "apparent chaos" as lessons are adjusted on the fly to meet the students' needs (p. 6). Beatty (2011) further summarizes the differences of the two methods by comparing lecturing and active learning to "class for presenting content vs. class for digesting content" (Beatty, 2011, p. 5). When 255 different studies were compiled to analyze the effect of active learning, it was found that active learning in any form increased average grades by half a letter grade and reduced failure rates by 45% (Freeman, et. al, 2014).

Classroom response systems (CRS), also called clickers, may be the answer to both student engagement and active knowledge composition (Beatty, 2004). Clickers are a low cost, active learning tool easily implemented by teachers and have been proven to increase engagement of the otherwise passive, unfocused student (Terrion & Aceti, 2012). Beatty (2011) describes his ideal classroom as being a place of Technology-Enhanced Formative Assessment, and his opinion is that this can best be achieved with clickers. Clickers are small handheld devices, similar in shape and function to cell phones. Each student uses the wireless device to answer a question posed by the teacher during class. This is usually done at a point in the lecture when the teacher traditionally pauses to call upon a single student to check for the understanding of the class (Terrion & Aceti, 2012). Answers are sent to the teacher's computer, and the software accompanying most clicker systems can then display a histogram of student responses. The teacher can choose to present these responses anonymously or assigned to the students' name. A whole class discussion can be launched or the teacher can make note of topics to clarify for the next class (Beatty, 2011).

One of many benefits of the use of clickers in the classroom is that there is, "a concerted focus on understanding rather than recall, and on reasoning rather than answers" (Beatty, 2004, p. 5). Accountability may be the initial motivating factor, but when students are engaged, they are more likely to be successful (Crews, Ducate, Rathel, Heid, & Bishoff, 2011). Clickers can be used as check points for basic understanding, so that when a student answers incorrectly it may provide reassurance that they are not alone, but hopefully also spur them to further analyze and fix their misconceptions (Beatty, 2004). When students reach the stage where they are able to self-evaluate their learning acquisition, they become engaged and willing participants in the nature of learning (Beatty, 2011).

One of many benefits of the use of clickers in the classroom is that there is, "a concerted focus on understanding rather than recall, and on reasoning rather than answers" (Beatty, 2004, p. 5). A study conducted by the Department of Biology at New Mexico State University demonstrated an increase in student exam scores across all levels and types of science classes with the implementation of classroom response clickers. Although their research did not address the reasons behind their findings, the authors put forward the possibility that the measured increase of scores could be due to a synergistic effect of the use of clickers and an unknown mechanism. Some of these possible influences working to raise grades alongside the use of clickers could have been increased social breaks to discuss topics with another student, the involvement of the type of student that would normally hang back, or the real time assessment feedback that benefits both students and teachers (Preszler, Dawe, Schuster & Shuster, 2006). Whatever the underlying reason, when students are engaged they are more likely to be successful (Crews, Ducate, Rathel, Heid, & Bishoff, 2011).

Clickers can be employed in the classroom in a variety of ways and situations to increase student's engagement and cognitive acquisition of knowledge (Preszler et. al., 2006). Clickers can be used as check points for basic understanding, so that when a student answers incorrectly it may provide reassurance that they are not alone, but, hopefully, also spur them on to further analyze and fix their misconceptions (Beatty, 2004). Other suggestions of potential clicker usage can be a brief quiz over the previous night's reading to check for comprehension. This allows the instructor to spend time efficiently focusing only on the material students were unable to comprehend on their own (Knight & Wood, 2005; Paschal, 2002). Other suggested applications include individual multiple-choice questions that concludes a peer discussion, or a series of questions at the beginning of a new topic to draw out students' prior knowledge on a subject (Beatty, 2004).

Another clicker technique often utilized by teachers is to keep clicker data and responses anonymous. According to Terrion and Aceti, if responses are displayed anonymously, students are often more willing to participate and potentially discover they have a misconception without the fear of personal embarrassment (2012). Crews et.al (2011) theorized at the end of their study that simply placing a clicker in the hands of students turns them into active learners, and active learners are reliably more invested in their own educational performance.

Whether clicker questions are used to elicit students' prior knowledge, used to spur a class discussion, or used anonymously to display the class's current comprehension level, Beatty (2004) warns that writing questions for clickers is "deceptively nontrivial" (p.6). A question that is simply rote memorization of a definition will produce a histogram with a perfect peak on the correct answer and will provide little insight to the teacher or students. A well-written clicker question should be somewhat ambiguous to draw students out and force them to fully examine their body of knowledge. Questions that confound students and require them to at times struggle towards new understandings are the most important points where students are "learning how to learn" (Beatty, 2004, p. 7)

Clickers have also been credited with facilitating students' development of their own metacognition, or in other words, an awareness of how and when they are learning. Deficiencies in metacognition development come from studies showing a marked disconnect in students between the body of knowledge they perceive they have mastered and the amount of knowledge they have in actuality mastered. This metacognition disconnect has also been noted in teachers. Often educators perceive their students have grasped more of the learning objectives than the final test scores ultimately (NRC, 2000).

When University of South Carolina instructors implemented clickers into their teaching methods, they were initially surprised by how inaccurate their assumptions were of their students' levels of understanding (Crews et. al., 2011). When used consistently as a part of the active learning process, clickers are able to clearly indicate to students when they are learning and how much they are learning. The goal is for students to reach the stage where they are able to self-evaluate their learning acquisition and become engaged and willing participants in the nature of learning (Beatty, 2011). Beatty (2004) summarizes this point when he says that with consistent and proper exposure, clickers can produce students who are "more motivated, empowered, aggressive learners" (Beatty, 2004, p. 9).

In summary, classroom response systems such as clickers have been shown to increase test scores and engagement, lower failure rates, and turn students into participants rather than observers (Preszler et. al., 2006). Clickers will not inherently bring about all of these changes, but their correct usage allows the teacher to address misconceptions and design more engaging and interactive learning experiences with instant feedback (Beatty, 2004).

METHODOLOGY

This study sought to quantify and qualify the effects the use of clickers had on students' level of science engagement and content acquisition. The research population was comprised of a somewhat transitory cohort of 47-55 sophomores taking an introductory biology class at Dubuque Senior High School during a five-month period. The research methodology for this project received an exemption by Montana State

University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

In order to measure students' engagement, the Science Engagement Likert Survey was administered at the beginning of the study as well as at the conclusion (Appendix B). The Science Engagement Likert Survey contained questions dealing with students' attitudes towards science as potential career, their opinions on the pace and ease of the content, and their ability to pay attention in class. The pre- and post- responses for this survey were collected and coded as 1 representing strongly disagree, 2 representing disagree, 3 representing agree, and 4 representing strongly agree. Each statement on this survey had a positive and negatively worded stem in order to make comparisons using stacked bar charts.

The Clicker Attitude Likert Survey contained questions designed to specifically elicit students' opinions surrounding the potential benefits and drawbacks of clickers (Appendix C). This survey was coded and scored the same as the Science Engagement Likert Survey with 1 representing strongly disagree, 2 representing disagree, 3 representing agree, and 4 representing strongly agree. Each statement of the Clicker Attitude Likert Survey had both a positive and negative stem in order to create a stacked bar chart of the data. Unlike the Science Engagement Likert Survey, the Clicker Attitude Survey was only taken at the end of the study.

The pre- and post-content quizzes accompanied both the treatment and non-treatment units in an effort to clearly demonstrate the effect the clickers had on students learning (Appendix D). Each assessment contained ten multiple-choice questions designed to elicit students' knowledge of the topic. These quizzes were scored as the number of correct answers out of ten. Each individual student's pre and post score was used to calculate individual normalized gains as well as the class average normalized gain. Median normalized gains less than 0.3 were classified as low gains, 0.3-0.7 were medium gains, and above 0.7 were high gains (Hake, 1998).

The units designated non-treatment were the mitosis, DNA, and Darwin units. Units designated treatment were the photosynthesis and cellular respiration, genetics, and basic evolution units.

Students used the clickers at the beginning and end of every period during treatment units. Typical use was five to eight questions presented as a multiple choice, true false, or Likert style. Questions posed to students fell into one of two categories; content type questions (Figure 1) or metacognition type questions (Figure 2).

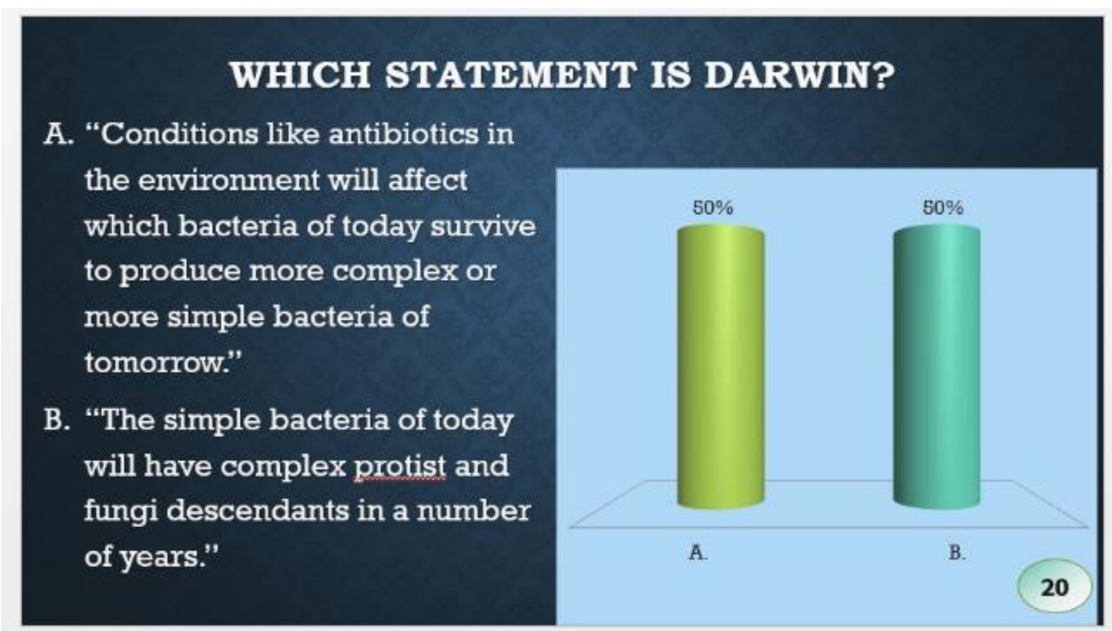

Figure 1. Example of clicker question categorized as content type.

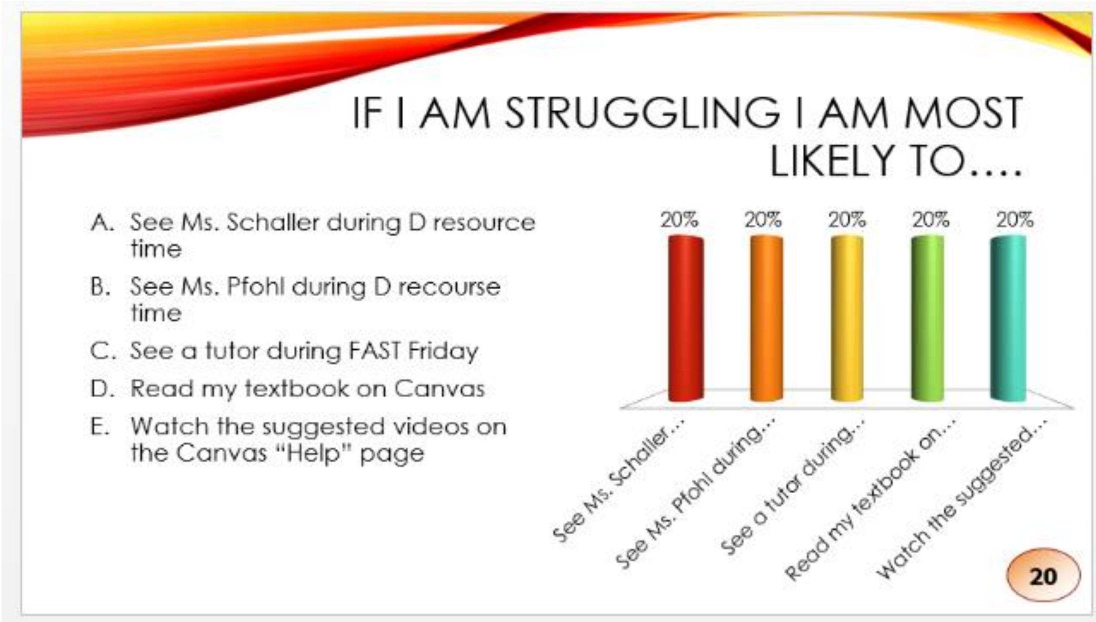

Figure 2. Example of clicker question categorized as metacognition type.

At the conclusion of the study, a Summative Student Interview was conducted with three students from each class for a total of nine (Appendix E). Students were asked their views on clickers in general, their insights into gains in their own learning, and their suggestions for the future implementation of the clickers. Interviews were conducted one on one and were recorded for reference purposes. The results of the student interviews were used as qualitative evidence to support the study (Table 1).

Table 1
Data Triangulation Matrix

Research Questions	Data Collection Instruments		
	1	2	3
Focus Question: Does the implementation of clickers improve students' engagement and content acquisition?	Content pre and post quizzes	Student pre and post engagement survey	Post interview questions
Secondary Questions: How do students' attitudes change towards science with the implementation of clickers?	Student pre and post engagement survey	Student pre and post clicker attitude survey	Post interview questions
Do students view clickers as beneficial to their learning	Student pre and post engagement survey	Student pre and post clicker attitude survey	Post interview questions

DATA AND ANALYSIS

The normalized gains for all six units comprising the study, both treatment and non-treatment, fell approximately between the range of 0.3 and 0.6, indicating medium growth in learning. The first treatment unit, photosynthesis and cellular respiration (*N*=47), had a median normalized gain of 0.42. The treatment units DNA (*N*=52) and Darwin (*N*=53) had normalized gains of 0.50 and 0.57 again indicating medium growth. The median normalized gains of the non-treatment units varied more than the treatment units, with the lowest median normalized gain attributed to the Evolution Unit (*N*=53), 0.38, followed by the Mitosis Unit (*N*=54), 0.55, and finally the Genetics Unit (*N*=53) 0.69. Side-by-side comparison of both treatment and non-treatment normalized gains is displayed in the box and whisker plots in Figure 3.

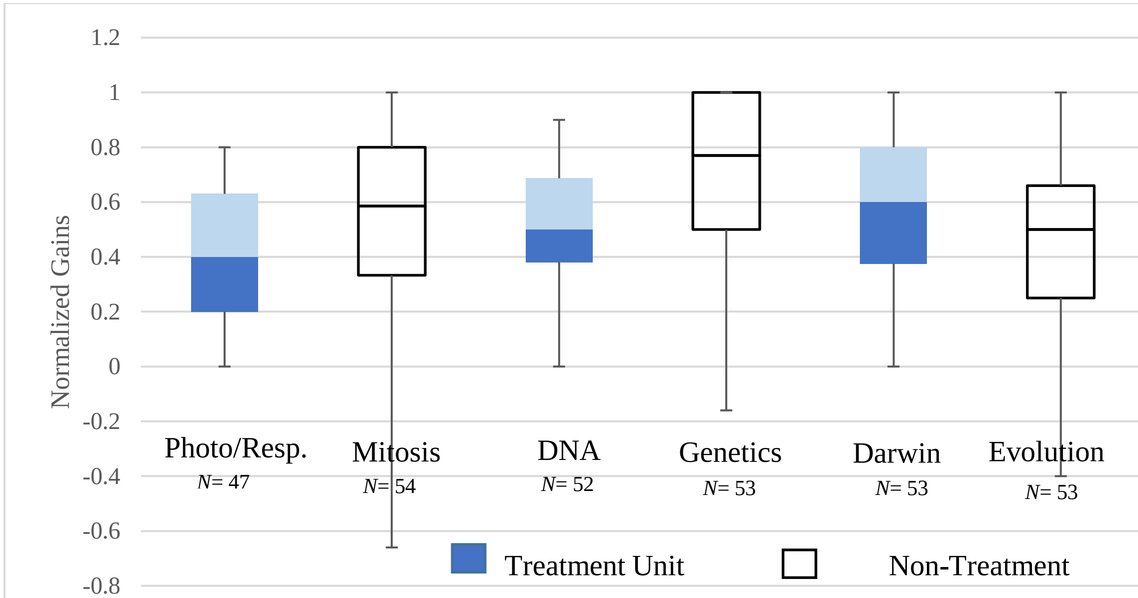

Figure 3. Normalized gains calculated from the pre- and post-content quizzes for both treatment and non-treatment units.

Despite the greater variation of individual unit's normalized gains seen in the non-treatment units, the combined average of all treatment units compared to the combined average of all non-treatment units was very similar. The average treatment unit normalized gain was 0.47 and the average non-treatment unit normalized gain was 0.56. Despite the closeness of the normalized gains, when one student was specifically asked if she noticed a difference between units where clickers were used and units where they were not, she replied, "I actually liked them (clicker units) a lot better because you got to know what you did know and what you didn't know, and you can know what you need to work on compared to what you were confident in." This is shown in the box and whisker plot in Figure 4 below.

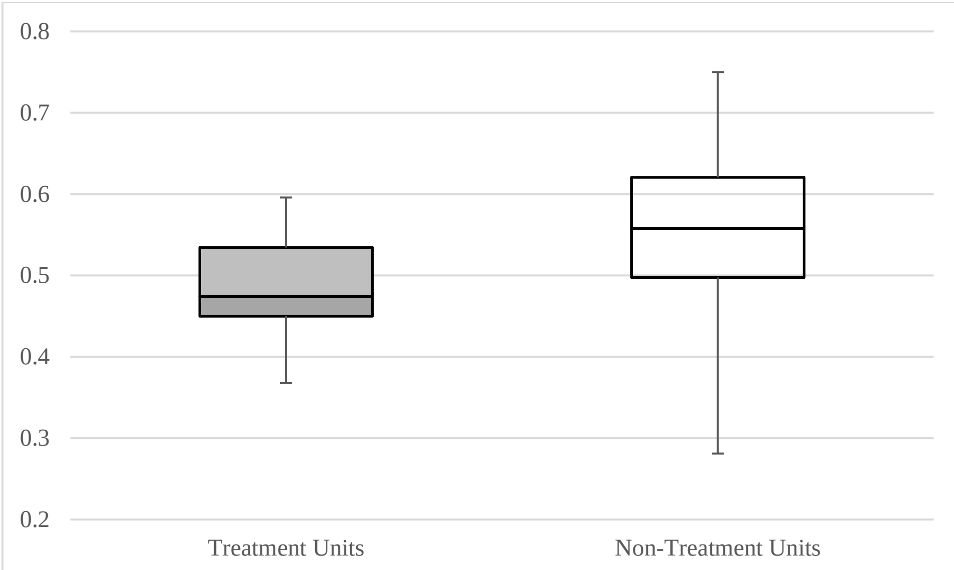

Figure 4. Compiled median normalized gains of all treatment versus non-treatment units, (*N*~50).

The Student Engagement Likert Survey maintained the overall trend of the study by displaying only small variances between pre and post surveys. One such survey question that demonstrated this was the positive stem, science class moves at a pace that is right for me and the negative stem, science class moves through material too quickly for me to keep up. The number of students who either agreed or strongly agreed with the positive stem increased from 65% to 74%. Correspondingly, the number of students who disagreed or strongly disagreed with the negative stem increased from 68.0% to 81% as seen in Figure 5.

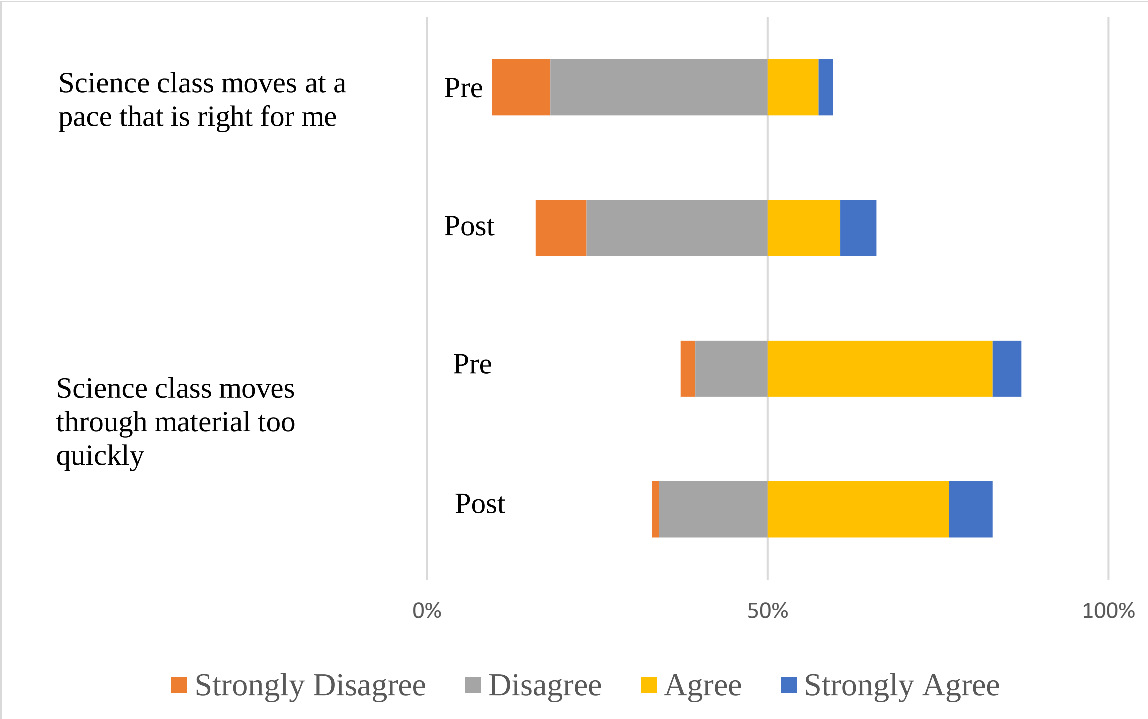

Figure 5. Results of the Student Engagement Likert Survey positive and negative stem questions regarding the pacing of the class, (*N*=47).

Another similarly correlated positive and negatively stemmed question was gleaned from the Student Engagement Likert Survey. This one regarded students' perception as to whether or not the activities and homework completed in class adequately prepared them for the test. The positive stem relating to the number of students who felt prepared for the test decreased between the pre and post survey from approximately 13% of combined agree and strongly agree responses to 11%. Relatedly, the number of students who responded that they strongly agreed to the negative stem of the question, indicating they did not feel adequately prepared for the test, increased from 19% to 26%. Despite this reported decrease in confidence and preparedness, on the actual survey questions more than one student contradicted their own Likert responses in comments left at the end of the survey or during the Summative Student Interview. One student shared that while responding to a clicker question that asked her to think about and examine how ready she felt for the upcoming test, that she suddenly understood she was “not ready at all.” She stated, “I realized I had to work harder and study for it” (Figure 6).

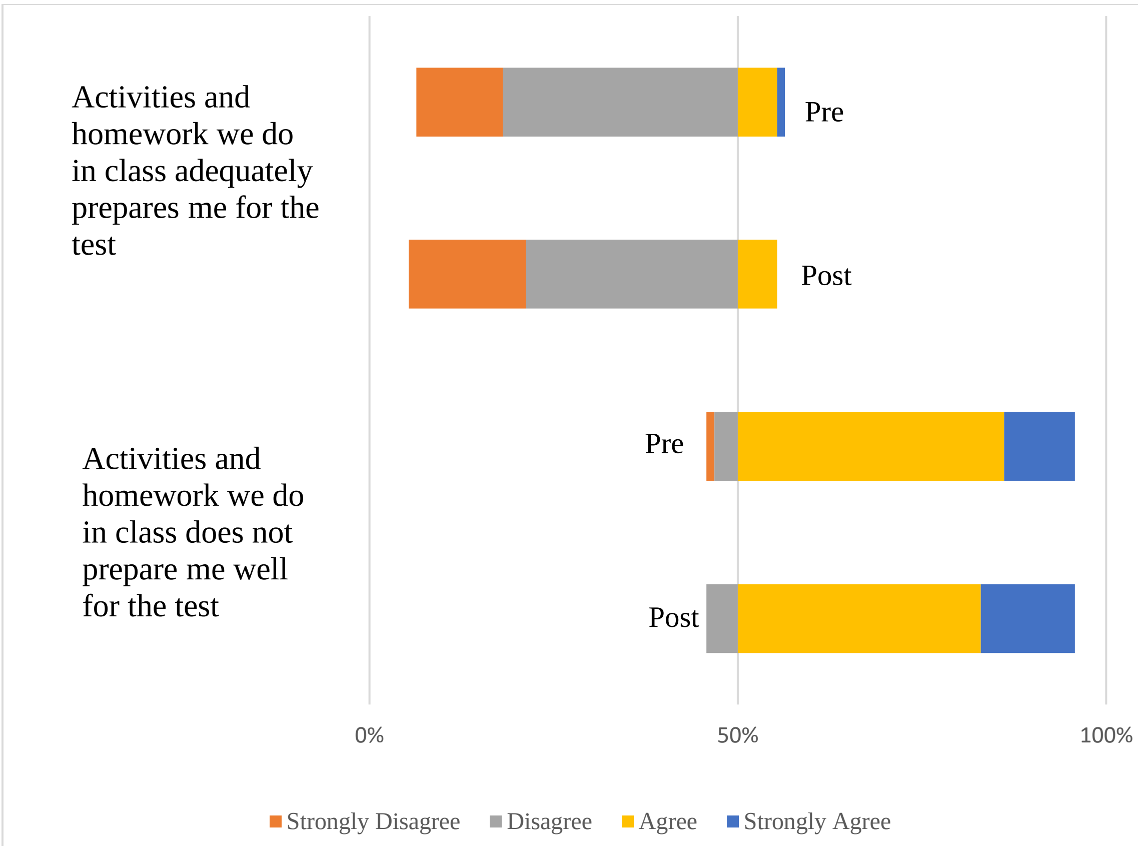

Figure 6. Results of the positive and negative stem regarding test preparedness from the Science Engagement Likert Survey, (*N*=47).

Results gathered from the Clicker Attitude survey revealed a slightly negative opinion surrounding the benefit of clicker use in helping students stay focused in class. Students who responded either agree or strongly agree to the negative stem, clickers have no effect on my focus in class, was 43% compared to only 39% of students responding the same to the positive stem, clickers help keep me focused in class. One student commented during their interview that if they were late to class, they were too flustered to focus on the clicker questions. They suggested that the response time should be "longer because some questions have so much stuff on it to figure out."

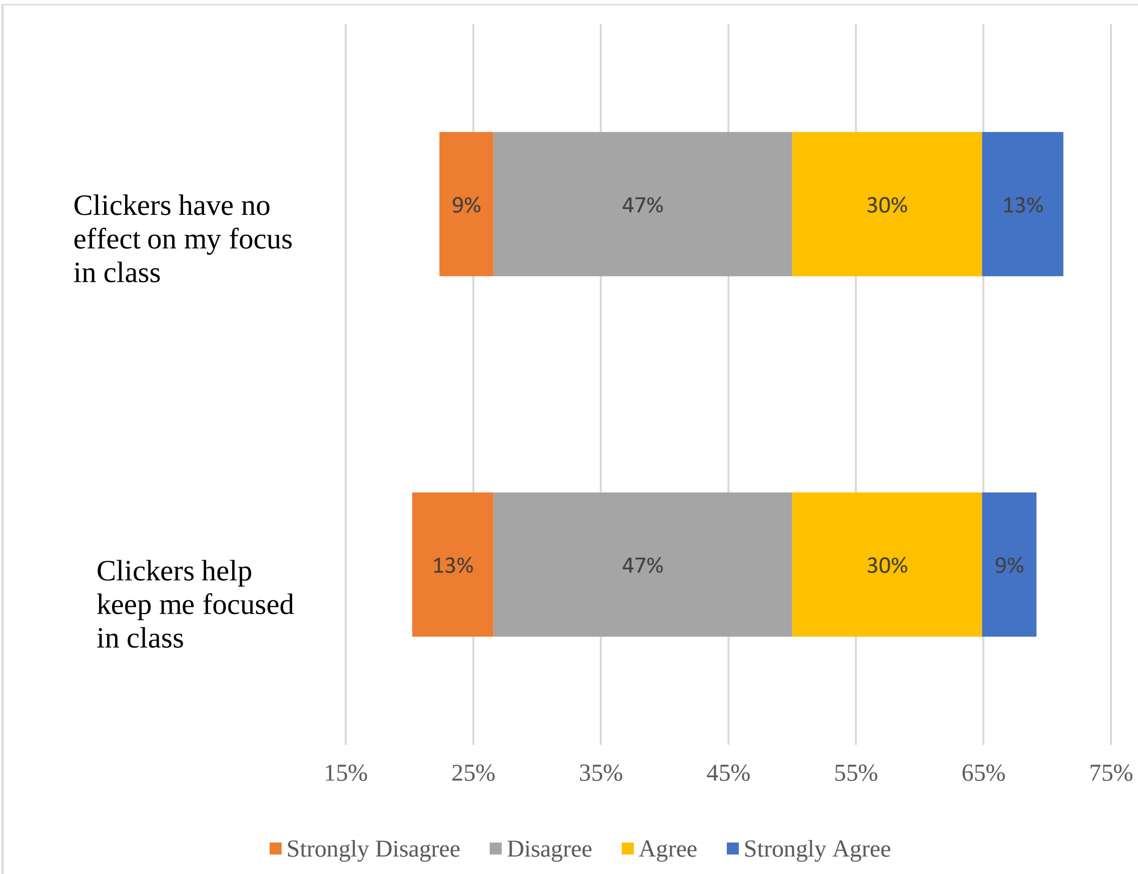

Figure 7. Results of the Clicker Attitude Survey regarding the topic of focus, (*N*=47).

The Clicker Attitude Survey questions revealed one of the only significant data points and dealt with the aspect of clickers helping students examine their own learning. Two students echoed what these data points revealed when one stated that "if you did bad on them you got a lot more practice in." Another confessed that he believed he was "more on top of his homework now. I think [clickers] help us. It's kind of a reminder." The results of these two survey statements revealed the percentage of students who responded agree to the positive stem, clickers help me discover my strengths and weaknesses, to be 62%. Congruently, the negative stem confirmed a similar percentage of students, 60%, disagreed with the statement, clickers do not help me discover what topics I should focus my studying on.

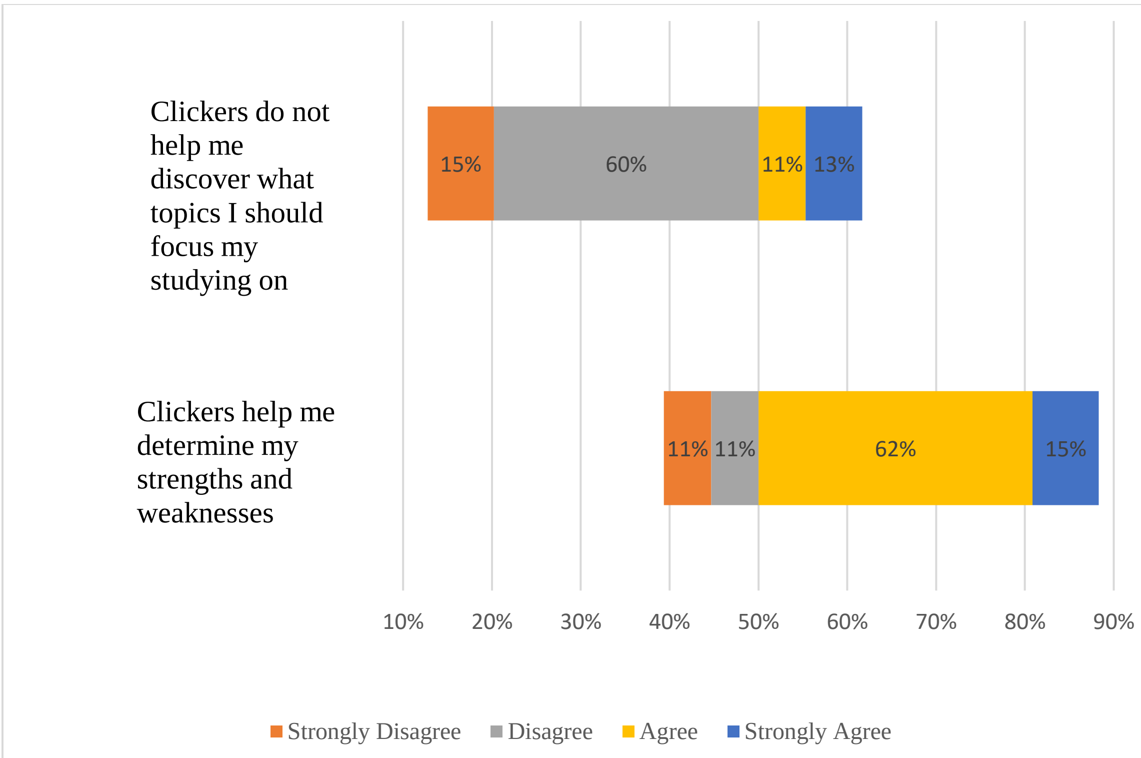

Figure 8. Results to the second positively stemmed and fourth negatively stemmed statement from the Clicker Attitude Survey regarding whether clickers help students elicit their current content mastery, (*N*=47).

INTREPRETATION AND CONCLUSION

Many leading researchers in the field of classroom response systems such as the previously mentioned Terrion, Aceti (2012), and Beatty (2004) tout clickers as the ultimate answer to the primary focus question of this study, does the implementation of clickers improve students' engagement and content acquisition? Although these experts would emphatically say "yes", my data is more ambiguous. Median content scores derived from the pre- and post-tests for each unit actually showed a very slight decrease in normalized gains in units where clickers were implemented compared to those units in which they were not.

I surmised that the minor normalized gain differences between treatment and non-treatment units can be attributed to the varying difficulty level of the units, and the small sample size compared to the afore mentioned authors. Unfortunately, for the purposes of a scientific study, each unit was not the same. Coincidentally, the units that were determined to be non-clicker units, were those topics in which, in my experience, students are more easily able to grasp and master with less time and effort. For example, the DNA unit, in which students generally have very little technical exposure beforehand to this material, was designated a treatment unit and the median normalized gain was 0.50. Directly following DNA comes Genetics, a non-treatment unit, where in traditionally students do have some previous background knowledge. My students finished this unit with the highest normalized gain score of all the units without the use of clickers. Normalized gains are used to account for differences in the complexity of the material and previous knowledge. I would venture to argue that Punnett squares are simply more intuitive than the unseeable helicase enzyme unzipping nucleotides, and without the help of clickers, the normalized gains for the DNA unit would have been even lower.

Despite the negligible difference in actual content scores between units taught using clickers and those without clickers, students still seemed to see the value in the method behind the clickers. One student wrote on her Clicker Attitude survey that, “It takes longer for me to understand things, and clickers give me more practice." Her sentiment was supported by the data in Figure 8 showing the majority of students agree with the sentiment that, clickers help me determine my strengths and weaknesses.

Finally, I anecdotally found direct ties between the later part of the primary focus question regarding student engagement, and the secondary focus question surrounding students being able to analyze their learning. For example, Figure 6 shows the increase in the percentage of students who reported not feeling prepared for the test, but as I witnessed this phenomenon, I realized this increase in their level of concern was actually an indication that they were beginning to think about their level of mastery and comprehend they had some deficits. Knowing when you do not know something is a remarkable achievement though hard to quantify in numbers.

VALUE

Regardless of nominal normalized gains, I viewed this classroom action research project as a success for both the students and myself as it was a springboard for further study and learning. Success came in the form of learning the benefits and professional procedures associated with action research for myself. I am empowered as an educator not only to try new techniques but to be able to quantitatively and qualitatively record and report my findings in the most professional way. I now have a vast array of tools and insights to determine when a teaching method is aiding my students and when it is not.

This study was also a success for my students despite their relatively unchanged pre- and post- engagement and content scores. Their success was evident in their responses to the Clicker Attitude Survey and their comments made during the summative student interviews. Comments such as, “I like the clickers. I think every teacher should teach with clickers,” was evidence of an increase in metacognition. Further evidence of this came from an increase in positive responses to the statement, “Clickers help me determine my strengths and weaknesses.” Being able to know what you know and what you don’t know is not an innate ability but one that must be consciously developed. I believe that clickers helped many of my students begin down this road to conscientious content acquisition.

I plan to continue to use clickers in my classroom with some modifications to the procedures that were used during this research project. The biggest of these changes is in the delivery of content type clicker question versus metacognition type questions. During the study, clicker questions were posed to students at the beginning of each class, and no order or distinction was made between the previously mentioned types of questions. I hypothesize that if these two types of questions were intentionally separated, for example, between the beginning and the end of class, students would separate their thinking. At the beginning of class their minds will be more focused on content, and towards the end of the period their minds will be more introspective of their learning.

The take away from this research for me personally was not the actual clicker device but the method. The process of getting kids settled and focused right after the bell rings with a series of questions has now become a consistent part of my class routine. Prior to this study I hadn’t given much conscious thought to students’ metacognition development. I mostly assumed it was a skill that couldn’t necessarily be learned but evolved over time. Today I am a better educator equipped with expertise in the area of action research that will allow me to be a practitioner of life long learning and continuous improvement to my craft.

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APPENDICIES

APPENDIX A

MONTANA STATE UNIVERSITY IRB EXEMPTION

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Micaela Schaller and John Graves

FROM: Mark Quinn *Mark Quinn CH*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: December 4, 2017

RE: *"Clickers in the High School Biology Classroom"* [MS120417-EX]

The above research, described in your submission of December 4, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

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

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

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

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

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

APPENDIX B

SCIENCE ENGAGEMENT LIKERT SURVEY

Directions: Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way. For each statement, check the box that matches your level of agreement.

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
1. Every citizen should understand science because we are living in an age of science.				
2. Activities and homework we do in class adequately prepares me for the test				
3. I am challenged in science class				
4. Science class moves at a pace that is right for me				
5. I like to study science and hope to work in a scientific field one day.				
6. Scientists have to study too much, and I would not want to be a scientist for this reason.				
7. Science class moves through material too quickly for me to keep up				
8. Science class is easy for me				
9. Spending a lot of time studying science is a waste of time now and in the future.				
10. Activities and homework we do in class do not prepare me well for the test				
11. Reasoning skills used to understand science can be helpful to me in my everyday life.				
12. There is no need for the public to understand science in order for scientific progress to occur.				
13. Is there anything else you want me to know?				

APPENDIX C

CLICKER ATTIDUDE SURVEY

Directions: Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way. For each statement, check the box that matches your level of agreement.

	Strongly Agree	Agree	Disagree	Strongly Disagree
1. Clickers help keep me focused in class				
2. Clickers help me determine my strengths and weaknesses before a test				
3. Clickers have no effect on my focus in class				
4. Clickers do not help me discover what topics I should focus my studying on.				
5. Is there anything else you want me to know?				

APPENDIX D

PRE AND POST CONTENT QUIZZES

Pre/Post Photosynthesis and Cellular Respiration

1.) What are the three parts of ATP?
   a. ________________
   b. ________________
   c. ________________

I can explain how plants and some other types of organisms get food. I can identify organisms that are photosynthetic

4. Organisms, such as plants, that make their own food are called ______________

5. Organisms that cannot make their own food must obtain energy from the foods they eat are called ______________

I know the overall equation for photosynthesis in chemical format and word format

6. Write the CHEMICAL equation for photosynthesis

7. Write the WORD equation for photosynthesis

I know the purpose of cellular respiration

8. ________Cellular respiration releases energy by breaking down

a. food molecules.
b. ADP.
c. carbon dioxide.
d. water.

I know the overall equation for cellular respiration in words

9. Write the equation for cellular respiration.

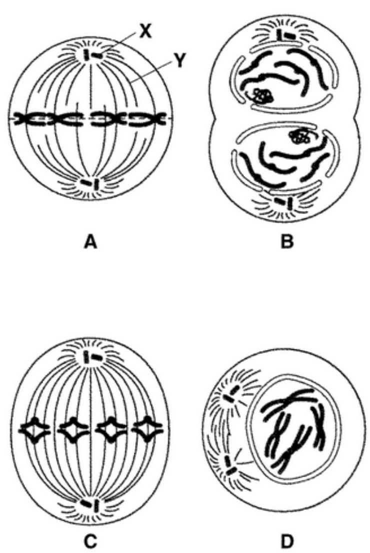
10. State the equation for cellular respiration in words:

Pre/Post Mitosis

1. How does the size of your cells as a baby compare to the size of your cells as an adult?
    a. Your cells are the same size when you are an adult; you just have more cells as an adult.
    b. Your cells are bigger when you are an adult; you have the same amount of cells as an adult as you do as a baby.
    c. Your cells are smaller when you are an adult, but you have many more cells as an adult.

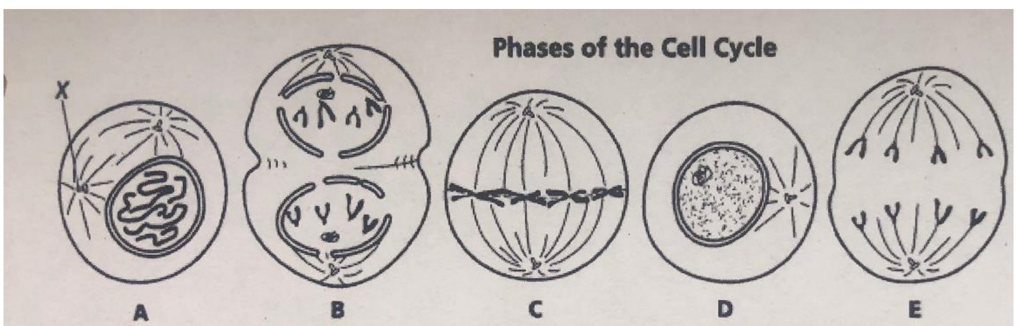
2. Right after a bone breaks, cells at the edge of the injury _________ ____________ in order to repair it.
    a. Grow bigger
    b. Stop dividing
    c. Form tumors
    d. Begin to divide

3. In a normal cell cycle,
    a. Mitosis takes more time than interphase
    b. Interphase takes more time than mitosis
    c. Mitosis and interphase take the same amount of time



4. Which of the following answers places the cells shown on the left in the correct sequence?
    a. A, B, C, D
    b. B, A, D, C
    c. D, A, C, B
    d. C, A, B, D

5. If a cell begins with 20 chromosomes at the beginning of mitosis, it will have ____ chromosomes in each daughter cell at the end of mitosis.
    a. 10
    b. 20
    c. 40
    d. 46
6. A cell undergoes cell division. At the end of cell division, there is/are:
    a. One cell with half as much DNA as the parent cell.
    b. Two identical cells with half as much DNA as the parent cell.
    c. One cell with a full set of DNA.
    d. Two identical cells with full sets of DNA.
7. The stage of the cell cycle that occupies most of the cell's life is
    a. Interphase
    b. G1
    c. M
    d. G2



8. Refer to the illustration above. During which stage do the centromeres divide?
    a. A
    b. B
    c. C
    d. D
    e. E
9. Refer to the illustration above. Which of the following correctly indicates the order in which these events occur?
    a. D, C, E, B, A
    b. D, A, C, E, B
    c. A, C, E, D, B
    d. B, E, C, D, A
10. Refer to the illustration above. The cell in diagram E is in ….

a. Prophase
b. Metaphase
c. Anaphase
d. Telophase

Pre/Post DNA and RNA

I can describe the structure of DNA

1. Draw and label a nucleotide

I can summarize the events of DNA **replication**.

2. Define Replication (what is the purpose)(from what to what)

3. Where does it take place?

4. Replicate this piece of DNA

GATCAACTTGGCA

I compare/contrast DNA and RNA.

5. List one difference between DNA and RNA

I can describe the process of **transcription**.

6. Define Transcription (what is the purpose)(from what to what)

7. Where does it take place?

8. Transcribe this segment of DNA into mRNA

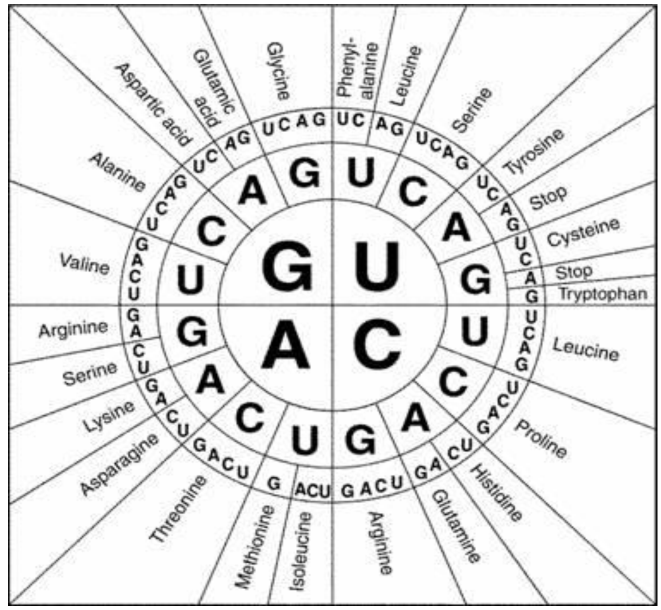
DNA: **TTGACGACTTGCCCATAG**

mRNA:

I can use the **genetic code** to name amino acids.

Using the genetic code to the right identify the amino acid

9. UCA



8.) I can describe the process of **translation**.

10. Define Translation (what is the purpose)(from what to what)

PRE/POST GENETICS

<u>Indicate if the following represent codominant traits "C" and which are incomplete dominant traits "I."</u>

1. ________ A bunny rabbit can have long, short, or medium ears.

2. ________ A dog can be white, black, or white with black spots.

- **<u>For each genotype below, indicate whether it is HETEROZYGOUS "HE" or HOMOZYGOUS "HO."</u>**

3. __________ Jj 4. __________ jj 5. __________ JJ

- **<u>Determine the *PHENOTYPE* for each genotype given. These are simple dominant and recessive traits</u>**

<u>IN PEAS:</u>	**R = round**	**T = tall**	**Y = yellow peas**	**P = purple flowers**
	r = wrinkled	**t = short**	**y = green peas**	**p = white flowers**

6. TT= ___________ **7. Tt = ___________** **8. tt = ______**

- **<u>This is a simple dominant and recessive trait monohybrid cross.</u>**

In a certain species of Unicorn, purple hair is dominant over white hair. Two heterozygous unicorns are crossed.

What is the percent of the offspring that have the following: 14.

9. PP = _________________

10. Pp = _________________

11. pp = _________________

12. Purple Hair = _________________

13. White Hair = _________________

- **<u>This is an incompletely dominant trait cross.</u>**

In four o'clock flowers red flowers "RR" are incompletely dominant to white flowers "rr." Show a cross between a heterozygous four o'clock flowers and a white flower.

What is the percent of the offspring that have the following:

15. RR=___________________

16. Rr=_________________

17. rr=__________________

18. Red=________________

19. White=________________

20. Pink=________________

<u>PRE/POST Darwin</u>

______ 1. Cows that give more milk than other cows are an example of

a. natural variation. c. survival of the fittest.

b. natural selection. d. struggle for existence.

______2. The practice of breeding dogs to produce offspring with specific traits is an example of

a. natural variation. c. common descent.

b. natural selection. d. artificial selection.

______3. Natural selection is the same as

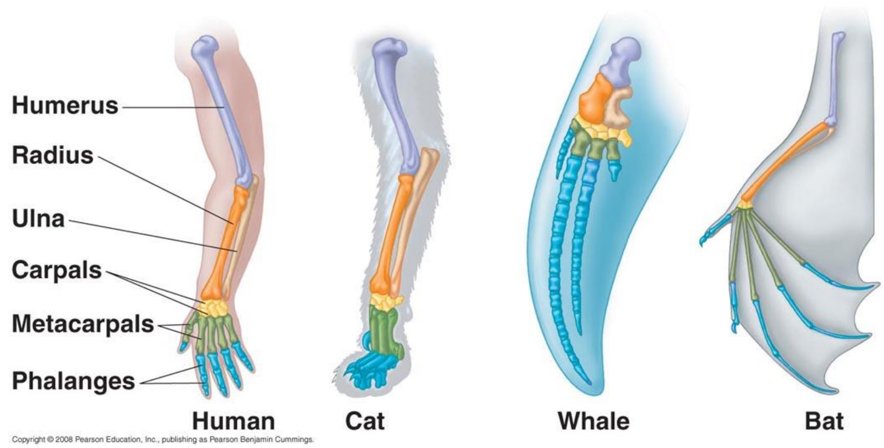
a. struggle for existence. c. artificial selection.

b. survival of the fittest. d. descent with modification.

______4. The diagrams of the limbs below show evidence of

a. natural variation.
c. common descent.

b. natural selection.
d. artificial selection.



______5. A human's appendix and a whale's pelvis are examples of

a. vestigial organs. c. natural selection.

b. fitness. d. artificial selection.

6. The idea that members of each species compete for necessities of life is known as

____

7. A is a well-supported, testable explanation of events that occur in the natural world.

____

8. The concept of survival of the fittest is also known as

____

9. Any inherited characteristic that increases an organism's chance of survival is a(an)

____

10. The idea that all species have evolved from shared ancestors is called

____________________________________.

PRE/POST EVOLUTION

______ 1. For most genes, a gene pool typically contains

a. no alleles.

b. two or more alleles.

c. one allele.

d. no more than two alleles.

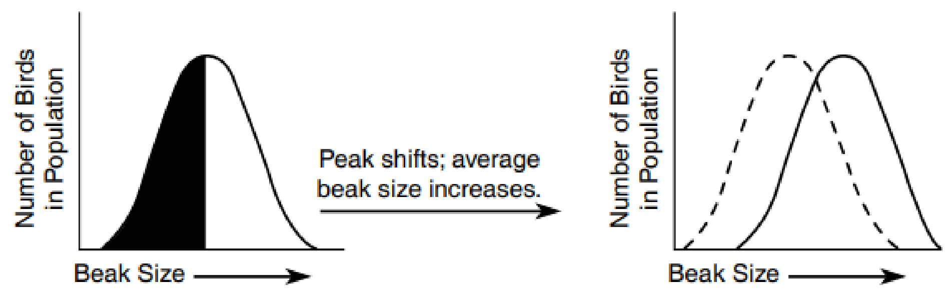
______ 2. The graphs below show changes in the distribution of beak size in Galápagos finches during a period when food was scarce. What type of natural selection do the graphs show?

a. directional selection

b. destabilizing selection

c. stabilizing selection

d. disruptive selection



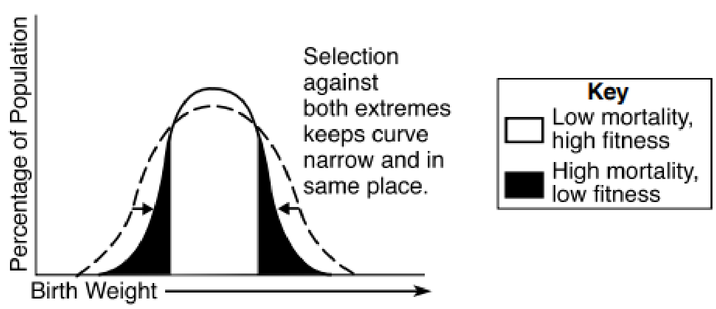
______ 3. The graph below shows the distribution of human birth weights. What type of selection keeps this curve narrow and in the same place?

a. directional selection

b. destabilizing selection

c. stabilizing selection

d. disruptive selection



4. A random change in allele frequency is called

a. fitness.

b. genetic drift.

c. speciation.

d. the founder effect.

______ 5. What occurs when allele frequencies change as a result of the migration of a small subgroup of a population?

a. directional selection c. speciation

b. the founder effect d. genetic equilibrium

______ 6. What is the formation of a new species called?

a. directional selection c. founder effect

b. speciation d. temporal isolation

______ 7. What situation occurs when members of two different species cannot interbreed and produce fertile offspring?

a. reproductive isolation c. genetic drift

b. genetic equilibrium d. natural selection

______ 8. What kind of isolation occurs when two populations are capable of interbreeding but have differences in courtship rituals or other types of behavior?

a. courtship isolation c. geographic isolation

b. behavioral isolation d. temporal isolation

______ 9. Two populations kept separate by a river are characterized by

a. genetic drift. c. geographic isolation.

b. disruptive selection. d. temporal isolation.

______ 10. What situation occurs when two or more species reproduce at different times?

a. stabilizing selection c. geographic isolation

b. behavioral isolation d. temporal isolation

APPENDIX E

SUMMATIVE STUDENT INTERVIEW QUESTIONS

Interview Questions

1. What are your thoughts on using the clickers? Overall, did you like it?

2. Specifically what is one thing you liked about using the clickers and one thing you did not like?

3. What differences did you notice in the ***way*** you learned material when you were using the clickers?

4. Is there any use or method of using the clickers that you think could be improved or should be changed?

5. Is there anything else you want to share about your experiences?