

THE EFFECT OF CLICKERS ON STUDENT ASSESSMENT SCORES
IN A HIGH SCHOOL BIOLOGY CLASSROOM

by

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ABSTRACT

Lectures are a great way to communicate a lot of material to a high school biology class, but that does not mean that the students actually participate and understand the material. In order to engage students and hopefully improve test scores, Qwizdom student response clickers were used during the first semester of the 2012-2013 school year in a high school biology classroom. The results from the chapter tests as well as the mid-term exam were compared to the results from the previous year's class, when clickers were not used. The clickers were shown to have a significant positive impact on assessment scores as well as student participation. Students and teachers felt that the clickers not only improved participation in class but also made the students focus more on the material.

INTRODUCTION AND BACKGROUND

DeMatha Catholic High School is an all-male private school in Prince George's County, Maryland. DeMatha has approximately 900 students, comprising approximately 53% African-American, 37% Caucasian students, 5% multiracial, 3% Hispanic, and 2% Asian (B. Coyle, Development Office, personal communication, April 23rd, 2013).

DeMatha recently acquired the Qwizdom Q4 handheld clickers. I was given the opportunity to use these in my biology classes, consisting of 75 students. These biology classes are taught at the college preparatory level, which means they are average students. The classes comprised approximately 78% freshman and 22% sophomores. These students tend to be motivated with a class average of a C. I had the chance to experiment with these clickers in my biology class during the fourth quarter of the 2011-2012 school year, and the students' responses were very positive. My students were much more engaged in the lecture when clickers were used and very excited about this new technology but were also upset they had not had the opportunity to use the clickers during the whole school year. With this positive reaction to the clickers, I wondered if I would see an increase in their assessment scores. I have always found that when my students are more engaged in the material, they tend to do better on assessments. I was hoping with the new-found engagement in the classroom, their assessment scores would increase.

This study occurred during the 2012 fall semester when the students were studying macro-biology concepts. This research examined whether clickers have an effect on long-term test scores and short-term test scores as well as the effects on students' interest, excitement and confidence when clickers are implemented during classroom instruction.

CONCEPTUAL FRAMEWORK

Teachers are always trying to find new methods of teaching in order to increase student participation and excitement in class. Within the last decade, teachers across different disciplines have started to turn to student response systems also called audience response systems or clickers (Caldwell, 2007; Preszler, Dawe, Shuster and Shuster, 2007). *Qwizdom's K-12 Education Brochure* (n.d.) says this new technology allows teachers to insert questions into lectures and receive an instant response from the student via handheld units, which each student has at their desk. The response from the student is then sent via radio frequency to the teacher's computer where it is tabulated and can be displayed to the teacher and/or the students. These responses show the teacher whether a class comprehends the material, which can allow a teacher to go back and re-teach the material. It also gives students instant feedback on their knowledge base of that particular subject.

Besides increasing the knowledge base, the use of clickers in the classroom can increase student participation in the classroom (Wood, 2004). It is assumed with increased student participation in the classroom, there is an increase in both long and short-term assessment scores. Short-term assessments are unit or chapter tests, whereas long term assessments refer to a semester or mid-term exam. Male students were shown to be more motivated and engaged when using clickers than female students. Male students tend to be more hesitant and less sure of themselves than females in the class. Because of this hesitation, they tend not to be as interactive in class. The use of the clickers may allow them to be more anonymous, which allows them to feel more

comfortable interacting in class. With this increase in interaction comes improvement in learning (Gok, 2011).

When students were surveyed about whether the clickers made a difference in comprehending the material, the majority responded that the clickers increased their understanding. Whether students feel like they are understanding material better or not, the true test is what the assessment scores show. Both assessment scores and survey responses showed that students do comprehend more when clickers are used during lecture (Preszler et al., 2007). With this increase in assessment scores, teachers also see an increase in overall course grades (Berry, 2009). Berry saw that when her class used clickers, their overall grades increased by two percentage points. Even the slightest increase in scores can be encouraging for students to study more.

When clickers are used in the classroom, the method in which they are used needs to be addressed. Preszler and colleagues (2007) showed a significant correlation between the frequency of the use of clickers in the classroom and an increase in test scores. In biology classes where clickers were used regularly, student test scores increased significantly from classes that sporadically used the clickers. If the use of the clickers does not occur regularly in class, then it is as if the teacher is just lecturing. It is critical that the implementation of the clicker be a regular part of the lecture in order for students to be constantly getting feedback as well as making sure the student is constantly engaged with the teacher (Preszler et al., 2007).

Even though some research shows a positive effect on student assessment scores when using clickers, some studies have not shown any significant effect (Matus & Summa, 2011; Karaman, 2011). It is thought that students are highly engaged with the

clickers when they are introduced, but once the “newness” of the clickers wears off, then student motivation is lost. Once motivation is lost, long-term assessment scores start to show no significant change (Karaman, 2011).

Clickers have also been shown to have a greater impact on students who are non-science majors in college, which would relate well to the experiment group of high school students. Wolter, Lundeborg, Kang and Herreid (2011) found an opposite result to Gok’s research, in which clickers were shown to be more effective when used by females than males. Hakkarainen and Palonen (2003) pointed out that females tend to be less affected by technology, which means that there should have been a smaller effect on females.

Clickers have also been shown to allow those students who are shy or tend to conform to voice their own opinion anonymously. Stowell, Oldham and Bennett (2010) found that shyness correlated with student preferences for using keypads, meaning shy students were more comfortable using the clickers than raising their hand in class. Stowell and colleagues also found that using clickers reduced conformity in the classroom. This means that if one asks opinion questions using the clickers that the responses will be less affected by peer pressure.

Besides raising student assessment scores, clickers have also been shown to increase participation in the classroom. Not only do clickers help those students who tend to be shy and conform to their peers, but they also help students who are not as interested in the material become more involved. Even though clickers have been shown to improve test scores, research has also pointed to a decrease in test scores when the excitement of new technology wears off.

METHODOLOGY

In order to examine the effects of clickers on short-term and long-term assessment scores, 127 students in college preparatory biology were surveyed during the fall of 2011 and the fall of 2012. The 66 students in the fall of 2011 did not have the opportunity to experience the clickers, as the resources had not yet become available. Since the clickers were not available, the 2011 group of students served as the non-treatment group. 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.

During the fall of 2012, clickers were interwoven within the lecture. The clickers presented multiple choice questions about the material presented in class and also were used to provide feedback on how well students understood the material being presented. I did not move on in lecture until all students had answered the question, and the answer had been discussed. I used the clickers mostly every day, but there were some days where the clickers were not used for one reason or another. The information from the student responses on the clickers was not averaged into the student's quarterly grade. Rather it was used solely as an assessment method to see if the students had mastered the material and if they were ready to move on to the next lesson.

In order to see if the clickers had an effect on student test scores, the same tests were administered to the group of students in my 2012 fall classes as were administered in my 2011 fall classes. The difference between the exam scores, both the pre and post treatment exams, between the two years were examined using a Welch's two sample t-

test. This statistical test was intended to show whether the understanding and comprehension of the students increased with the use of the clickers in the classroom.

One facet of this research looked at the effects of the clickers on short-term retention. Another facet of this research looked at the effects of clickers on long-term retention. In order to look at long-term test scores, the 2011 and 2012 Biology Mid-Term Exam scores from the fall 2011 group of biology students were compared with the scores of the fall 2012 (Appendix A). If the mid-term exam questions differed from year to year, only similar questions were compared.

In addition to looking at exam scores, students were also interviewed. Students were chosen randomly from my three sections of college preparatory biology and were asked questions from the Student Clicker Interview Questionnaire (Appendix B). The same students were interviewed after every unit exam as well as after the mid-term exam. These interviews pointed out changing attitudes as the study progresses. The responses of these interviews were recorded as well as written down. This data were then analyzed for common themes.

Since all the students were not interviewed due to time constraints, the students were surveyed at the beginning and end of the treatment. The Student Clicker Survey used a Likert scale and open-ended questions (Appendix C). If students *strongly agreed*, *agreed*, was *neutral*, *disagreed* or *strongly disagreed* with the statement then they circled a five, four, three, two or one, respectively. The statements in the Student Clicker Survey focused on three different aspects. The first aspect was about quiz and test preparation. The second aspect concentrated on student understanding and focus in the classroom. The third aspect examined whether students thought their achievement was improved with the

use of clickers. This survey allowed for more quantitative data to be collected. These data were analyzed using the Chi-Squared Goodness of Fit statistical test in order to see if the opinions of the students changed over the length of the study (Table 1).

Observations were also made and recorded during the class. These observations were noted in an electronic journal. Observations were made at the end of most teaching periods. These observations were used to help explain the behavior in the classroom while clickers were being used as well as when clickers were not being used.

Table 1
Data Triangulation Matrix

Research Question	Data Source 1	Data Source 2	Data Source 3
Primary Question: Do clickers affect long-term and short-term exam scores?	Test scores from unit exams and mid-term exams	Student Survey	Student Interviews
Secondary Question: Do clickers improve confidence in taking a test?	Student Survey	Student Interviews	Teacher Observations
Secondary Question: Do clickers make it easier for students to study?	Student Survey	Student Interviews	Teacher Observations

DATA AND ANALYSIS

The average test scores for all six college preparatory biology classes were examined (Table 2). The averages for all the tests that were administered in 2011-2012 and 2012-2013 were averaged for all the students that took the test each year. Chapters 1, 13 and 14 were all pre-treatment exam scores. Students in 2011-2012 scored higher on chapter 1, 13 and 14 by 8.9, 6.98, and 2.08 percentage points than the 2012-2013 students, respectively. Treatment occurred during chapters 16, 2 and 3. The 2012-2013

students scored 1.73 and 10.87 percentage points higher than the 2011-2012 students on the Chapter 16 and Chapter 13, respectively.

A Welch's Two Sample t-test was used to compare the chapter test scores between the 2011-2012 students and the 2012-2013 students. For the Chapter 1 test, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between 13.0 and 4.5% (Welch's Two Sample t-test, $t = -4.0717$, $df = 116.8$, $p\text{-value} = <0.0001$). The 2011-2012 cohort scored higher on the Chapter 1 test. For the Chapter 13 test, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between 11.0 and 2.0% (Welch's Two Sample t-test, $t = -2.889$, $df = 119.993$, $p\text{-value} = 0.004587$). The 2011-2012 cohort scored higher on the Chapter 13 test. For the Chapter 14 test, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between -6.9 and 2.4% (Welch's Two Sample t-test, $t = -0.9586$, $df = 121.219$, $p\text{-value} = 0.3397$). The Chapter 14 test did not show a statistical difference between the two cohorts. For the Chapter 16 test, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between -2.0 and 5.4% (Welch's Two Sample t-test, $t = 0.8929$, $df = 122.185$, $p\text{-value} = 0.3737$). The Chapter 16 test did not show a statistical difference between the two cohorts. For the Chapter 2 test, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between -7.3 and 2.2% (Welch's Two Sample t-test, $t = -1.0785$, $df = 118.706$, $p\text{-value} = 0.283$). The chapter 2 test did not show a statistical difference between the two cohorts. For the Chapter 3 test, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between 5.8 and 15.7% (Welch's Two

Sample t-test, $t = 4.3145$, $df = 117.999$, $p\text{-value} = <0.0001$). The 2012-2013 cohort scored higher on the Chapter 3 test. Even though not all the exams showed a statistical difference, they definitely showed a positive trend for an increase in assessment scores when clickers were used.

Table 2
Average Test Scores by Chapter and Year, (N = 127)

	Chapter 1	Chapter 13	Chapter 14	Chapter 16	Chapter 2	Chapter 3	Mid-term
2012-2013 students	70.7	70.7	63.6	77.8	60.8	66.9	71.9
2011-2012 students	79.6	77.7	65.6	76.1	63.5	56.0	71.1
p-value	<0.0001	0.00458	0.3397	0.3737	0.283	<0.0001	0.7129

The same mid-term exam was given to both groups of students. The 2012 group of students scored less than 1% higher than the 2011 biology students. For the mid-term exam, a 95% confidence interval for the difference between the 2011-2012 cohort and the 2012-2013 cohort was between -3.3 and 4.8% (Welch's Two Sample t-test, $t = 0.3688$, $df = 124.853$, $p\text{-value} = 0.7129$). The mid-term exam did not show a statistical difference between the two cohorts. This was not significant but showed a trend towards a positive effect from the clickers (Figure 1).

This increase in assessment scores was also noted in my observations. Students also stated on the Clicker Student Survey as well as in the Student Clicker Interview Questions that "They [the clickers] helped me pay attention." One student also said, "The clickers made me listen better and take better notes during lecture."

When students used the clickers, they got immediate feedback on whether the answers were correct. One student said in the interview, “The fact it told me if my answer was right or wrong helped me better understand the material.” Another student mentioned on the Clicker Student Survey, “Because the clickers were hands-on, we treated them like a game.” Students viewed the clickers as interactive, which allowed them to relax and absorb the material more.

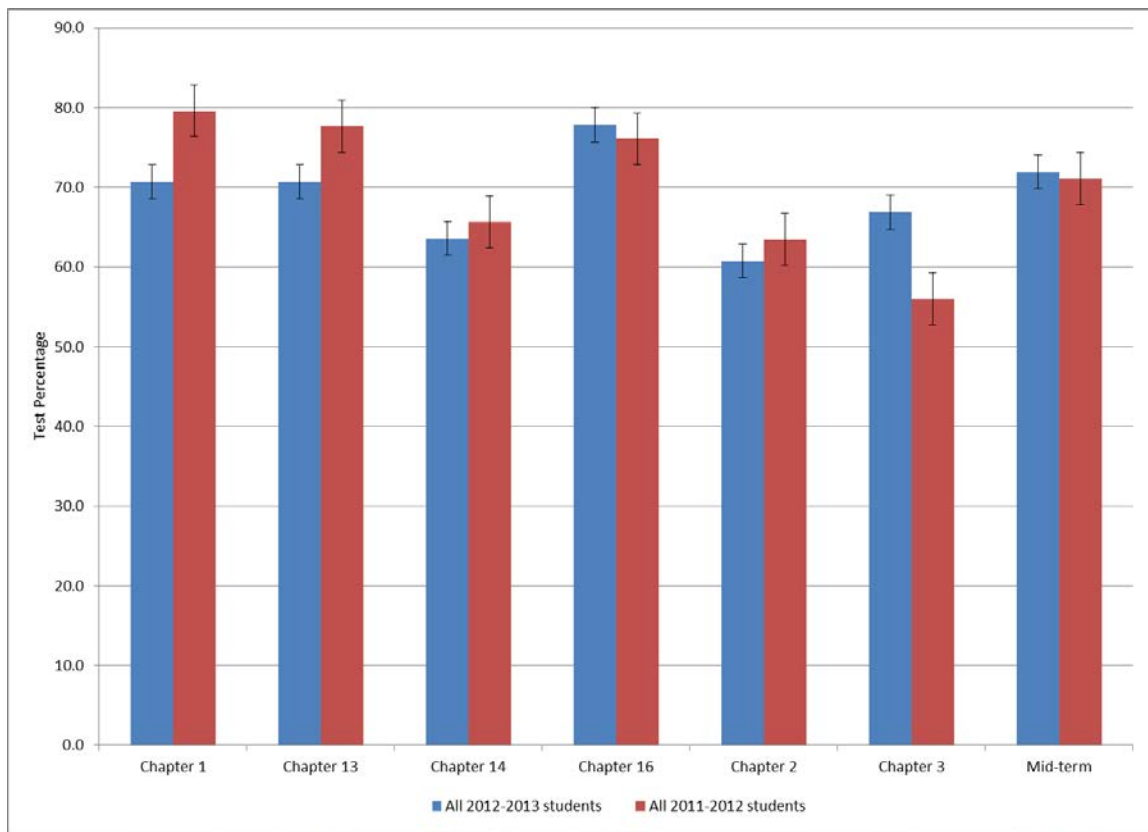


Figure 1. Test percentages between 2011-2012 and 2012-2013 biology students. The first three tests were pre-treatment. The last 4 tests were post-treatment, ($N = 127$).

On the Clicker Student Survey, students overall impression of the clickers decreased over this period of time. When the survey was first administered, 58% of students either *strongly agreed* or *agreed* the clickers had an impact on their achievement in biology. But when the survey was given again, this number dropped to 49%. When

asked whether the clickers helped better prepare students for quizzes, 73% *agreed* or *strongly agreed*, which then jumped to 79% during the post-treatment administration of the survey (Figure 2). Students' opinion decreased when asked whether the clickers helped them better prepare for the chapter test. Pre-treatment 78% of students *agreed* or *strongly agreed* and post-treatment 73% of students *agreed* or *strongly agreed* with the statement (Figure 3).

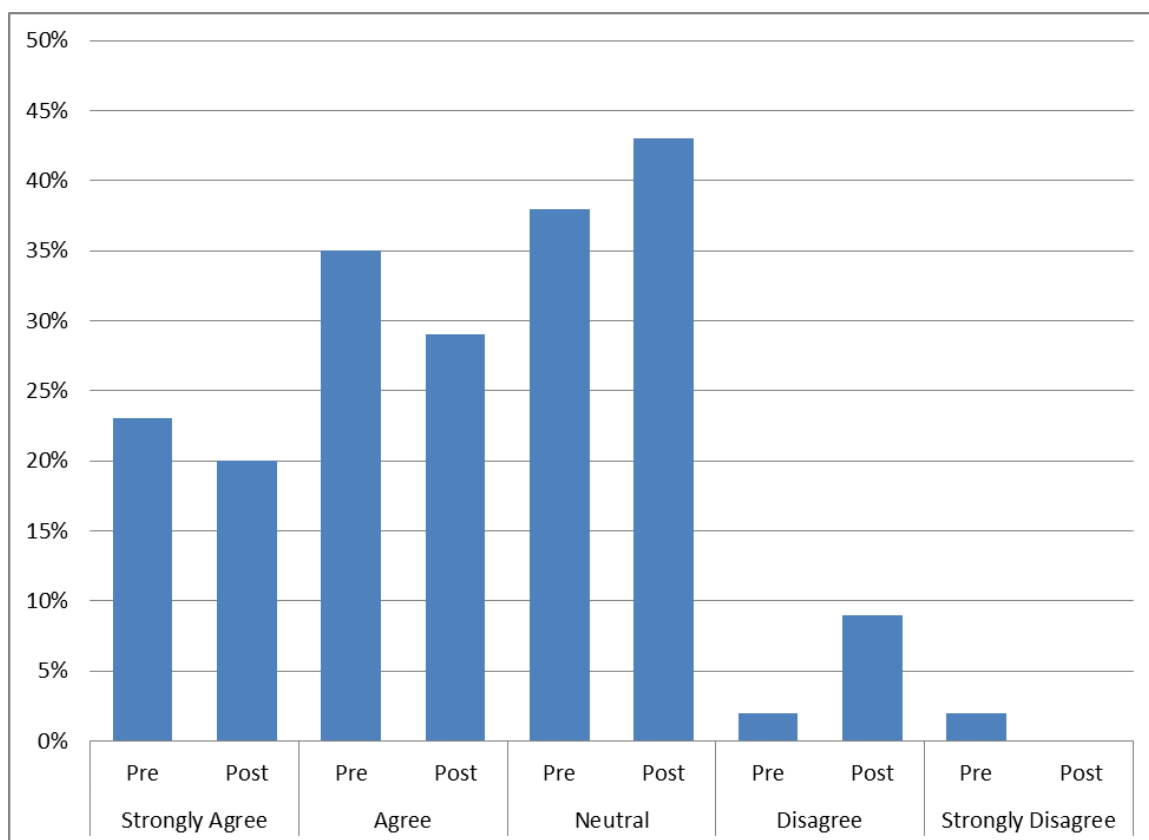


Figure 2. Comparison between pre-treatment and post-treatment student clicker survey responses on the impact of achievement in biology, ($N = 56$).

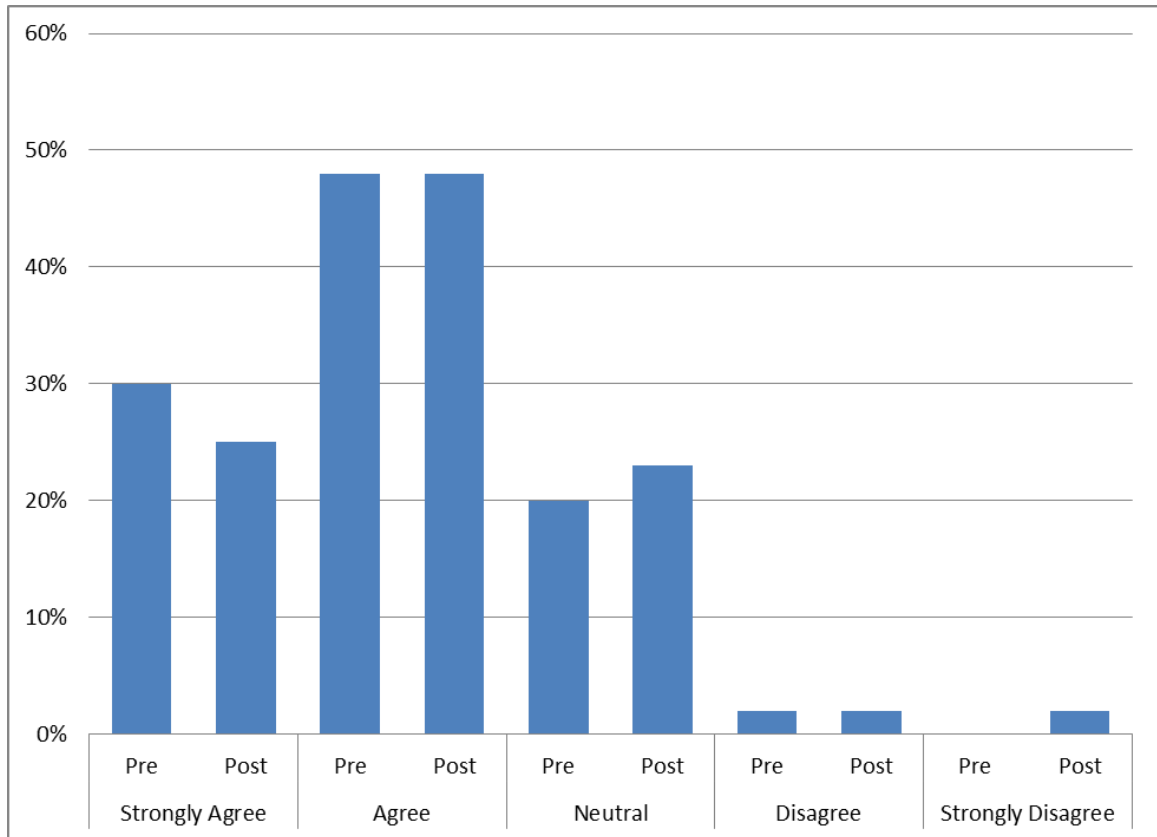


Figure 3. Comparison between pre-treatment and post-treatment student clicker survey responses on being better prepared for chapter test, ($N = 56$).

The results between the pre-treatment and post-treatment Student Clicker Surveys were statistical analyzed. There was a statistical difference in all the questions on the survey except the questions that asked about preparation for tests and quizzes (Table 3). Students did not see a perceived improvement in preparation of tests and quizzes between the two times the survey was given, even though there was an increase in test scores.

Table 3
P-values for the Clicker Student Survey (N = 56).

Questions Asked	p value
The clickers helped me better prepare for the chapter test.	0.8391
The clickers helped me better review the material presented in class.	<0.001
The clickers helped me better prepare for the quizzes.	0.505
It was good to get immediate feedback on the clickers so that I could better understand the material.	<0.001
I paid better attention to lecture when clickers were used.	0.0224
The clickers helped me better stay focused during the lecture.	0.018
The clickers had a significant impact on my participation in biology.	0.001237
The clickers had a significant impact on my achievement in biology.	<0.001

INTERPRETATION AND CONCLUSION

When the scores from the pre-treatment exams were examined, it was obvious the 2011-2012 cohort of students was a stronger class. Their grades on the exams tended to be higher, but then once I started treatment, the exams scores from the 2012-2013 cohort of students started to rise. As the treatment progressed, the difference between the averages grew larger and larger. Even though not all the results were statistically

significant, the results definitely showed an upward trend of improvement in the test scores when clickers were used. The first three tests of the semester, the 2011-2012 cohort scored higher, and then once clickers were used, the 2012-2013 cohort scored higher on the chapter tests. This was probably due to an increase in participation in class which caused the students to pay attention. The students in the 2012-2013 were also accidentally forced to study a few days out from the test rather than cram for the test due to the review game. They wanted to win and reviewed for the game which was played the day before the test.

The long-term test scores did not appear to change dramatically. I believe if the clickers had been used more throughout the entire semester, then there would have been a greater change in the mid-term test scores. In order to get results that are statistically significant, more testing may be necessary.

It was interesting the students tended to not agree as much with the questions on the Student Clicker Survey between the first time and the last time the survey was administered. Even though their test scores rose, the perception of the effectiveness of the clickers declined. I don't believe the students realized their test scores had risen, especially since they took the second survey right after they had received their mid-term grades in class. In retrospect, I wish another survey could have been given about a month later when they were not using clickers in the class.

I continued to observe the class before and during the use of the clickers. I made many notes about the students, which showed that students tended to be more disruptive and less focused during those days when the clickers were not used. I made one particular note during one of the review games we played prior to the test, where I stated "This is

the most engaged I have ever seen my students in studying for biology in the last 4 years of teaching.” It was truly amazing to me to see my students actually arguing about science rather than sports or something else not related to my class. The students were much more engaged and actively participated in class when the clickers were used.

I recently gave the set of clickers to my department chair who is starting to use them in his honors and advanced placement classes. My students now constantly ask if we can use the clickers during lecture. It is a great sign because they know that it has helped them to better understand biology. My hope is that more of my department members will start using them.

VALUE

This study really opened my eyes to the way students interact in a classroom. I started taking notes on my computer about who was talking, being disruptive in class, or who was actively participating after every class period at the start of the year. It took me a few minutes to write my comments after each class, but it became a great log of activity in my classroom. It was fascinating to then watch those disruptive students become more engaged in the class when clickers were used.

I ended up using one of the games that came with the Qwizdom software package, and students were even more engaged. I had never seen my students completely focused on biology. Students would move all around the projector so that they could see the screen. Every student wanted to be the first to answer. My students did not realize that by “playing” with the clickers they were actually starting to study for my exams earlier rather than just simply the night before the exam. This is one of the possible reasons that their assessment scores increased.

We did not always play a game with the clickers; most days I was either reviewing the material or making sure my students understood the material. Since I teach all boys, they are always competing with one another. This ended up being a great way to get them to study their notes every day.

This project also gave me a better understanding of statistics. If you ask a researcher what they do first during a study, they will tell you they design the experiment and then find a statistical test to fit. If you ask a statistician what you do first, they will tell you to find a statistical test and then design the experiment around it. I was definitely in the former category. However, I believe I may have learned my lesson. I thoroughly struggled to figure out the statistics with this project. It took a lot of experimenting and a lot of question asking, but I did finally figure out some statistical tests that worked.

This capstone project has definitely had a major impact on my teaching style in two ways. First, I have started to engage students a lot more in my lectures, especially when I do not use clickers. I have found that most of my students' behavior problems stem from them not being challenged enough. I now do not give them time to become bored and therefore avoid this issue. Besides constantly asking questions, I am constantly reviewing previous slides. I find that it keeps my students more focused and less likely to start dreaming. They know I will just randomly call on them, and typically I call on the students that do appear to be day dreaming.

The second big thing that I learned from this project was my need to keep experimenting and doing research. I had a great time collecting the data and looking for trends in the data. I would love to keep working on this project and keep getting more data points over the next few years. It would be interesting to me to see if the trend

continues. Besides just looking at the use of clickers, I would like to see if other pedagogical methods of engaging my students in the classroom, like POGIL (Process Oriented Guided Inquiry Learning), would increase assessment scores.

Lastly, this whole process has affected the way I approach my teaching. Before this process, I would look at just simply the questions my students got wrong on a test. But now after this process, I talk to students a lot more. I have learned their opinions are more valuable to adapting my teaching style than any set of numbers that I could collect. Plus, my students value the fact that I actually listen and adapt my teaching style to better help them learn. My goal is to continue to change my teaching style and do miniature research projects, so that I can see whether that change affected my students.

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APPENDICES

APPENDIX A

2011 AND 2012 BIOLOGY MID-TERM EXAM

Name: _____ Class: _____ Date: _____

2012 Biology Mid-term Exam

Multiple Choice

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

- ____ 1. Scientists use observation and data to form and test
 - a. constants
 - b. hypotheses
 - c. theories
 - d. conclusions
- ____ 2. The study of life is called
 - a. scientology
 - b. chemistry
 - c. physics
 - d. biology
- ____ 3. When a hypothesis has been repeatedly and rigorously tested and supported, it is called a
 - a. scientific theory
 - b. scientific model
 - c. testable prediction
 - d. scientific method
- ____ 4. Which of the following follows observation in the scientific method?
 - a. hypothesis
 - b. experiment
 - c. conclusion
 - d. question
- ____ 5. An organized system of testing a hypothesis is a(n)
 - a. experiment
 - b. analysis
 - c. conclusion
 - d. observation
- ____ 6. During an experiment, which factors are observed and measured?
 - a. dependent variables
 - b. independent variables
 - c. constants
 - d. hypotheses
- ____ 7. The instrument used to measure and extract very SMALL amounts of liquid is
 - a. pipette
 - b. test tube
 - c. flask
 - d. beaker
- ____ 8. All science begins with
 - a. hypothesis
 - b. observation
 - c. question
 - d. theory
- ____ 9. Which of the following have the same meaning?
 - a. heterotroph/autotroph
 - b. autotroph/consumer
 - c. heterotroph/producer
 - d. autotroph/producer

- ____ 10. Another name for the independent variable is
- a. dependent
 - b. resulting
 - c. responding
 - d. manipulated
- ____ 11. At which stage of scientific thinking are scientists most likely to consider the data and conclusions of other scientists to propose new experiments?
- a. observing
 - b. testing hypotheses
 - c. analyzing data
 - d. forming hypotheses
- ____ 12. The variety of life across the biosphere is called
- a. biodiversity
 - b. genomics
 - c. homeostasis
 - d. ecology
- ____ 13. About 12 to 24 hours after the last meal, a person's blood sugar level normally varies from 60 to 90 milligrams per 100 milliliters of blood, although it may rise to 130 mg per 100 ml after meals high in carbohydrates. That the blood sugar level is maintained within a fairly narrow range, despite uneven intake of sugar, is due to the body's ability to carry out
- a. inheritance
 - b. metabolism
 - c. homeostasis
 - d. all of these
- ____ 14. The instructions for growth and development are in
- a. DNA
 - b. carbohydrates
 - c. proteins
 - d. energy
- ____ 15. As energy is transferred among organisms, some escapes into the environment as ____ energy.
- a. electrical
 - b. light
 - c. mechanical
 - d. heat
- ____ 16. Which is the smallest unit of life that can survive and reproduce on its own?
- a. cell
 - b. atom
 - c. molecule
 - d. organ
- ____ 17. A mutation is a change in
- a. homeostasis
 - b. metabolism
 - c. hereditary instructions
 - d. the life cycle of an organism
- ____ 18. All of the coyotes (*Anis latrans*) living in the Mojave Desert constitute a(n)
- a. ecosystem
 - b. population
 - c. organism
 - d. community

- ____ 19. An inherited trait that helps an organism to better survive is a(n)
a. homeostasis
b. mutation
c. adaptation
d. microscope
- ____ 20. Similar organisms that can reproduce by interbreeding belong to the same
a. ecosystem
b. environment
c. habitat
d. species
- ____ 21. Which of the following is defined as “all of the various species living in the same area”?
a. community
b. ecosystem
c. biosphere
d. population
- ____ 22. Cells that work together are organized into
a. organism
b. tissue
c. organ
d. organ system
- ____ 23. All the chemical processes used to build up or break down material are called an organism's
a. metabolism
b. homeostasis
c. adaptations
d. stimuli
- ____ 24. What is the name given for genetic changes in living things over time?
a. adaptation
b. homeostasis
c. evolution
d. negative feedback
- ____ 25. A physical environment with different species that interact with one another and nonliving things is called a(n)
a. biosphere
b. ecosystem
c. habitat
d. adaptation
- ____ 26. The container used to measure liquids accurately is the
a. beaker
b. flask
c. mug
d. graduated cylinder
- ____ 27. Mixing liquids is most easily done with less splashing in
a. graduated cylinders
b. flasks
c. test tubes
d. beakers

- ____ 28. Which is true about a dependent variable in an experiment?
- It is the experimental data.
 - It is manipulated by a scientist
 - It never changes during the experiment.
 - It is not affected by the independent variable.
- ____ 29. On Earth, biodiversity generally increases from the
- poles to the equator
 - equator to the rainforest
 - east to the west
 - north to the south
- ____ 30. Which phrase best describes an ecosystem?
- all living things and the places on Earth where they are found
 - organisms interacting with each other and with nonliving things in a certain region
 - the variety of organisms on Earth or in a particular area of the biosphere
 - a group of living things that can interbreed to reproduce
- ____ 31. The smallest basic unit of matter is the
- molecule
 - atom
 - compound
 - cell
- ____ 32. Which of the following is formed when an atom gains or loses electrons?
- element
 - compound
 - molecule
 - ion
- ____ 33. The atomic number is determined by the number of
- neutrons and protons
 - protons and electrons
 - neutrons and electrons
 - protons only
- ____ 34. Which substance is NOT an element?
- water
 - oxygen
 - chlorine
 - hydrogen
- ____ 35. Atoms in molecules share pairs of electrons when they make
- covalent bonds
 - ionic bonds
 - hydrogen bonds
 - polymers
- ____ 36. For an atom to be neutral, _____ must have the same number.
- electrons and neutrons
 - neutrons and protons
 - electrons and protons
 - electrons, neutrons, and protons
- ____ 37. The nucleus of an atom contains
- neutrons and electrons
 - neutrons and protons
 - protons and electrons
 - protons only

- ____ 38. Of the following, pH_____ is the most acidic.
- a. 1
 - b. 3
 - c. 6
 - d. 7
- ____ 39. Which of the following elements is important to organisms because of its bonding versatility?
- a. hydrogen
 - b. oxygen
 - c. nitrogen
 - d. carbon
- ____ 40. The element with the smallest mass is
- a. lead
 - b. carbon
 - c. sodium
 - d. hydrogen
- ____ 41. What gives water many properties that are important to living things?
- a. temperature
 - b. hydrogen bonds
 - c. density
 - d. specific heat
- ____ 42. The bond in table salt (NaCl) is
- a. polar
 - b. hydrogen
 - c. covalent
 - d. ionic
- ____ 43. Which components of an atom are arranged in various energy levels?
- a. protons and electrons
 - b. electrons
 - c. protons
 - d. neutrons
- ____ 44. Three of the four solutions listed below are acidic. Select the exception.
- a. vinegar
 - b. cola
 - c. soap
 - d. lemon juice
- ____ 45. Which of the following is neutral on the pH scale?
- a. sea water
 - b. acid rain
 - c. tap water
 - d. pure water
- ____ 46. The negative subatomic particle is the
- a. neutron and proton
 - b. neutron
 - c. proton
 - d. electron
- ____ 47. Which of the following solutions has the highest H⁺ ion concentration?
- a. a solution with a pH of 1
 - b. a solution with a pH of 4
 - c. a solution with a pH of 7
 - d. a solution with a pH of 10

- ____ 48. The smallest portion of a substance that retains the properties of an element is
- atom
 - compound
 - molecule
 - ion
- ____ 49. What is unique about carbon?
- bonding properties
 - properties as reactant
 - ability to bond with oxygen
 - properties as an enzyme
- ____ 50. Which substance is NOT a compound?
- salt
 - methane
 - chlorine
 - carbohydrate
- ____ 51. Which substance represented in Figure 2.1 (A or B) is the solvent?
- both A and B
 - substance A
 - substance B
 - neither A nor B
- ____ 52. The four main types of carbon-based molecules in organisms are carbohydrates, lipids, nucleic acids, and
- starches.
 - fatty acids.
 - monosaccharaides.
 - proteins.
- ____ 53. Substances are changed into different substances when bonds break and form during
- chemical equilibrium.
 - chemical reactions.
 - ion formation.
 - hydrogen bonding.
- ____ 54. Identify the products in this reaction: $6\text{H}_2\text{O} + 6\text{CO}_2 \text{ -----} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$.
- $6\text{H}_2\text{O}$ and 6CO_2
 - 6CO_2 and $\text{C}_6\text{H}_{12}\text{O}_6$
 - $6\text{H}_2\text{O}$, $\text{C}_6\text{H}_{12}\text{O}_6$, and 6O_2
 - $\text{C}_6\text{H}_{12}\text{O}_6$ and 6O_2
- ____ 55. Chemical reactions that absorb more energy than they release are called
- exothermic.
 - catalyzed.
 - endothermic.
 - activated.
- ____ 56. The neutral subatomic particle is the
- neutron
 - proton
 - electron
 - neutron and protons
- ____ 57. The activation energy needed for a chemical reaction is decreased by a
- catalyst.
 - reactant.
 - product.
 - substrate.

- ____ 58. Which aspect of a chemical reaction is affected by enzymes?
 - a. direction
 - b. rate
 - c. equilibrium
 - d. pH
- ____ 59. This organic compound is the most abundant and is also an instant source of energy.
 - a. carbohydrate
 - b. protein
 - c. lipid
 - d. nucleic acid
- ____ 60. How do ions form?
 - a. Atoms combine to make a larger atom.
 - b. Two atoms share electrons.
 - c. Atoms form covalent bonds.
 - d. Atoms gain or lose electrons.
- ____ 61. What does the diagram in Figure 13.1 show?
 - a. the nitrogen cycle
 - b. the water cycle
 - c. the oxygen cycle
 - d. the carbon cycle
- ____ 62. Herbivores are which of the following?
 - a. producers
 - b. secondary consumers
 - c. primary consumers
 - d. decomposers
- ____ 63. Which phrase best describes biodiversity?
 - a. the number of individuals in an ecosystem
 - b. the amount of biomass in an ecosystem
 - c. the amount of available energy in an ecosystem
 - d. the number of species in an ecosystem
- ____ 64. Which organisms help convert gaseous nitrogen into ammonia in the nitrogen cycle?
 - a. bacteria
 - b. trees
 - c. squirrels
 - d. grasses
- ____ 65. Organisms that feed on dead or decaying matter are called
 - a. herbivores.
 - b. carnivores.
 - c. omnivores.
 - d. detritivores.
- ____ 66. What do all the biotic and abiotic factors in a given area make up?
 - a. a habitat
 - b. a community
 - c. an ecosystem
 - d. a population
- ____ 67. Which of the following parts of Figure 13.2 is an example of a biotic factor?
 - a. sunlight
 - b. soil
 - c. deer
 - d. river

- ____ 68. Which model shows the number of organisms at each trophic level in an ecosystem?
- biomass pyramid
 - food web
 - pyramid of numbers
 - food chain
- ____ 69. Which of the following provide most of the energy in ecosystems?
- keystone species
 - carnivores
 - generalists
 - producers
- ____ 70. Almost all autotrophs get their energy from
- sunlight.
 - hydrothermal pools.
 - decaying matter.
 - producers.
- ____ 71. An organism that has an unusually large effect on an ecosystem is called a(n)
- keystone species.
 - omnivore.
 - biotic factor.
 - heterotroph.
- ____ 72. A major regional or global community of organisms is called
- an ecosystem.
 - a biome.
 - a species.
 - a population.
- ____ 73. A pyramid of numbers is used to show
- the distribution of biomass in an ecosystem.
 - a network of feeding relationships.
 - the distribution of organisms in an ecosystem.
 - a chain of feeding relationships.
- ____ 74. Which statement is true of producers?
- They consume most of the biomass in ecosystems.
 - They fix most of the nitrogen in ecosystems.
 - They produce most of the carbon dioxide in ecosystems.
 - They provide most of the energy in ecosystems.
- ____ 75. Zebras live on the savannas of Africa. A watering hole on the savanna would be part of a zebra's
- biotic factors.
 - niche.
 - habitat.
 - behavior.
- ____ 76. When two species compete for the same resource, they sometimes divide this resource. This is an example of
- niche partitioning.
 - niche equivalency.
 - evolutionary response.
 - ecological equivalence.

- ____ 77. The mantella frog and poison dart frog occupy similar niches in similar habitats in different parts of the world.
Because of this, they are considered to be
- a. competitors.
 - b. the same species.
 - c. interacting populations.
 - d. ecological equivalents.
- ____ 78. Hawks and foxes compete to eat field mice. This is a form of
- a. interspecific competition.
 - b. competitive exclusion.
 - c. intraspecific predation.
 - d. random dispersion.
- ____ 79. What word or phrase would be most appropriate opposite "Commensalism" under "Organism 2"?
- a. may die over time
 - b. neither benefits nor is harmed
 - c. benefits
 - d. is harmed
- ____ 80. Which of these is an example of parasitism?
- a. A lion defends its territory.
 - b. A squirrel stores food in a tree hole.
 - c. A leech feeds on a host's blood.
 - d. A polar bear kills and eats a seal.
- ____ 81. To measure population density, you must divide the number of individuals living in a defined space by the
- a. perimeter of the area.
 - b. area of the space.
 - c. birth and death rates.
 - d. carrying capacity.
- ____ 82. Nesting birds often space themselves evenly from other nests. This pattern is called
- a. clumped dispersion.
 - b. uniform dispersion.
 - c. random dispersion.
 - d. type I dispersion.
- ____ 83. Which type of organism would be most likely to have a type II survivorship curve?
- a. one that protects and cares for its young
 - b. one that preys on small mammals
 - c. one that is preyed upon throughout its life
 - d. one that has high birth and infant mortality rates
- ____ 84. Which of the following will increase the size of a population?
- a. emigration and deaths
 - b. immigration and deaths
 - c. emigration and births
 - d. immigration and births
- ____ 85. Which of the following is a density-dependent limiting factor?
- a. natural disaster
 - b. unusual weather
 - c. human activities
 - d. competition

- ____ 86. What type of population growth is shown in the graph?
- logistic growth
 - exponential growth
 - density-dependent growth
 - carrying capacity growth
- ____ 87. Hawaii's lush tropical forests arose from a process of
- succession.
 - predation.
 - regeneration.
 - destruction.
- ____ 88. Pioneer species are the first
- trees to grow in an area that has been disturbed.
 - trees that replace the original trees after a forest fire.
 - organisms to live in previously uninhabited areas.
 - organisms to live in a forest canopy.
- ____ 89. The reestablishment of a damaged ecosystem in an area where the soil is intact is called
- primary succession.
 - secondary succession.
 - pioneer succession.
 - symbiotic succession.
- ____ 90. The white-tailed deer and the kangaroo are both large herbivorous mammals that occupy similar niches but live on different continents. They are an example of
- ecological equivalents.
 - competitors.
 - niche partitioning.
 - competitive exclusion.
- ____ 91. A herd of caribou has more births than deaths and more immigration than emigration. What will most likely happen to the size of the herd?
- It will increase.
 - It will decrease.
 - It will increase, and then decrease.
 - It will stay the same.
- ____ 92. In 1988 several large forest fires occurred in Yellowstone National Park. What process occurred after these fires?
- primary succession
 - secondary succession
 - pioneer succession
 - symbiotic succession
- ____ 93. How many people can Earth support?
- 10 billion
 - 20 billion
 - 50 billion
 - an unknown number
- ____ 94. What are renewable resources?
- resources that are used faster than they form
 - resources that can replenish themselves over time
 - resources that formed over millions of years
 - resources that exist only in rural areas

- ____ 95. What would Earth be like without the greenhouse effect?
- a. too cold to be habitable
 - b. a little cooler than it is now
 - c. the same temperature as it is now
 - d. a little warmer than it is now
- ____ 96. According to the graph, by how much did the world population increase between 1950 and the last actual recorded population?
- a. It increased by 8 billion.
 - b. It increased by 4 billion.
 - c. It doubled.
 - d. It quadrupled.
- ____ 97. What factors interact to produce smog?
- a. particulates and pollutants from fossil fuels
 - b. sunlight and oxygen
 - c. sunlight and pollutants from fossil fuels
 - d. sunlight and acid rain
- ____ 98. Which level of the food chain is most affected by biomagnification?
- a. producers
 - b. primary consumers
 - c. secondary consumers
 - d. tertiary consumers
- ____ 99. In what biome is biodiversity the highest?
- a. temperate forests
 - b. grasslands
 - c. tropical rain forests
 - d. deserts
- ____ 100. Because the manatee is an umbrella species, protecting it may lead to
- a. pollution of waterways.
 - b. decreased seagrass.
 - c. increased boating in their habitat.
 - d. protection of many other species.
- ____ 101. Why is firewood considered to be a renewable resource?
- a. It can be replenished over time.
 - b. It is used up faster than it can form.
 - c. It is made from coal.
 - d. It can be made synthetically.
- ____ 102. Canned tuna made from small fish is generally considered to be safer to eat than canned tuna from large fish. Large fish have more pollutants
- a. because they drink more water.
 - b. because they live in more polluted water.
 - c. due to their larger surface area.
 - d. due to biomagnification.
- ____ 103. Organisms designated as producers usually obtain their energy from
- a. other producers
 - b. dead consumers
 - c. decomposers
 - d. the sun

For questions 104 and 105, A scientist randomly divided a group of 100 lab rats into two groups of 50. One group was fed regular rat chow while the other was fed the same amount of rat chow with added DDT. Both groups were housed in the same room with the same environmental conditions. At the end of the experiment, rats were weighed and the mean difference calculated.

- ____ 104. What variable(s) was/were manipulated by the scientist?
- a. DDT
 - b. temperature
 - c. weight differences
 - d. both DDT and weight differences
- ____ 105. What dependent variable was measured?
- a. DDT
 - b. temperature
 - c. weight
 - d. amount of food
- ____ 106. The positive subatomic particle is the
- a. neutron
 - b. proton
 - c. electron
 - d. neutron and proton
- ____ 107. An atom of sodium has an atomic number of 11 and a mass of 23. How many neutrons does it have?
- a. 11
 - b. 12
 - c. 23
 - d. 34
- ____ 108. How do hydrophobic molecules react with water?
- a. attracted to
 - b. absorbed by
 - c. repelled by
 - d. mixed with
- ____ 109. The total number of individuals of the same species that occupy a given area at a given time is the
- a. population distribution
 - b. population growth
 - c. population birth rate
 - d. population size
- ____ 110. The average number of individuals of the same species per unit of surface area at a given time is the
- a. population density
 - b. population growth
 - c. population birth rate
 - d. population size
- ____ 111. A situation in which the birth rate equals the death rate is called
- a. an intrinsic limiting factor
 - b. exponential growth
 - c. saturation
 - d. zero population growth

- ____ 112. A population that is growing exponentially in the absence of limiting factors can be illustrated by which curve?
- a. S-shaped
 - b. J-shaped
 - c. one that terminates in a plateau phase
 - d. bimodal
- ____ 113. A J-shaped growth curve is converted to an S-shaped one
- a. when the parents are past reproductive age
 - b. if the data are plotted in reverse
 - c. when the carrying capacity is reached
 - d. if reproduction stops
- ____ 114. Interaction between resource availability and a population's tolerance to prevailing environmental conditions defines
- a. the carrying capacity of the environment
 - b. exponential growth
 - c. the doubling time of a population
 - d. density-independent factors
- ____ 115. A change in a population that is not related strictly to the size of the population is best described as
- a. density-dependent
 - b. density-independent
 - c. an S-shaped curve
 - d. a J-shaped curve
- ____ 116. In itself, a flood that washes away an entire population of rabbits is
- a. a density-dependent factor
 - b. a limiting factor dependent on the individuals
 - c. a consequence of exponential growth
 - d. density-independent
- ____ 117. Which density-dependent factor controls the size of a population?
- a. wind velocity
 - b. light intensity
 - c. nutrient supply
 - d. rainfall
- ____ 118. Which is not a density-dependent, growth-limiting factor?
- a. predation
 - b. drought
 - c. parasitism
 - d. competition
- ____ 119. A type III survivorship curve (mortality high at birth and decreasing with age) is characteristic of all but which species?
- a. flies
 - b. humans
 - c. frogs
 - d. reptiles
- ____ 120. Organisms that demonstrate a type I survivorship curve are characterized by
- a. high *reproductive rate*, small offspring
 - b. low *reproductive rate*, small offspring
 - c. low *reproductive rate*, large offspring
 - d. high *reproductive rate*, large offspring

- ____ 121. The most reasonable method of limiting human population growth is
- increasing carrying capacity
 - decreasing birth rate
 - decreasing competition
 - increasing death rate
- ____ 122. Niche refers to the
- home range of an animal
 - preferred habitat of an organism
 - functional role of a species in the community
 - territory occupied by a species
- ____ 123. A one-way relationship in which one species benefits at the expense of another is called
- commensalism
 - symbiosis
 - parasitism
 - mutualism
- ____ 124. Which of the following would be more likely to affect an animal's habitat than its niche?
- rainfall
 - prey abundance
 - predators
 - defense mechanisms
- ____ 125. A relationship in which two species are dependent on each other for survival is
- neutral interaction
 - competitive exclusion
 - mutualism
 - parasitism
- ____ 126. The interaction between two species in which both species are harmed is known as
- mutualism
 - parasitism
 - commensalism
 - competition
- ____ 127. The relationship between an insect and the plants it pollinates is best described as
- mutualism
 - competitive exclusion
 - parasitism
 - commensalism
- ____ 128. Niche overlap initially leads to
- mutualism
 - commensalism
 - competition
 - predation
- ____ 129. Which is(are) an adaptation against predation?
- thorns
 - camouflage
 - mimicry
 - all of the above

- ____ 130. The coexistence of 12 species of fruit-eating pigeons in New Guinea is an example of
- competition
 - social parasitism
 - predation
 - resource partitioning
- ____ 131. Which is an example of warning coloration?
- the dark brown mane of a lion
 - the bright green and blue feathers of a peacock
 - the black and yellow bands of a wasp
 - the black and white stripes of a zebra
- ____ 132. Hoverflies are attracted to sweets at outdoor picnics. The reaction of humans is usually to flee because of the flies' uncanny resemblance to bees. The survival of hoverflies is enhanced by
- mimicry
 - camouflage
 - warning coloration
 - chemical defenses
- ____ 133. Which of the following represent an early stage in primary succession?
- pine trees
 - moss and lichens on bare rock
 - weedy annual plants in an open field
 - climax species in succession
- ____ 134. In a natural community, primary consumers are
- herbivores
 - carnivores
 - scavengers
 - decomposers
- ____ 135. Which of the following is NOT dependent on the others as a food supply?
- carnivores
 - herbivores
 - producers
 - detritivores
- ____ 136. Chemosynthetic organisms are
- primary consumers
 - secondary consumers
 - tertiary consumers
 - primary producers
- ____ 137. The ultimate source of energy in a terrestrial ecosystem is
- the organic matter in all the organisms of the ecosystem
 - water
 - sunlight
 - carbon dioxide
- ____ 138. In biological magnification,
- Poisons accumulate in the high ends of food chains and webs.
 - There is a tendency for an environment to change when organisms first invade.
 - More highly evolved forms are able to build large populations under favorable conditions.
 - Parasites spread rapidly through congested populations.

- ____ 139. Detritivores are
 - a. bacteria
 - b. plants
 - c. fungi
 - d. bacteria and fungi
- ____ 140. At the bottom or base of a pyramid of energy are the
 - a. primary producers
 - b. secondary producers
 - c. primary consumers
 - d. tertiary consumers
- ____ 141. The biomass of a community is the weight of the
 - a. material decomposed in a year
 - b. producers
 - c. living organisms
 - d. consumers
- ____ 142. Which is NOT part of the nitrogen cycle?
 - a. denitrification
 - b. deammonification
 - c. nitrogen fixation
 - d. ammonification
- ____ 143. Nitrification
 - a. converts ammonia into nitrates
 - b. reduces nitrates to nitrites
 - c. converts nitrogenous compounds into free nitrogen
 - d. is a synonym for nitrogen fixation
- ____ 144. Three of the four answers listed below are heterotrophic. Select the exception.
 - a. consumers
 - b. herbivores
 - c. carnivores
 - d. producers
- ____ 145. The distribution of the human population in the United States is
 - a. clumped
 - b. random
 - c. uniform
 - d. constant

Matching

Answer questions 146 - 149 by matching the statement to the most appropriate function, process, or trait listed below.

- a. metabolism
- b. reproduction
- c. photosynthesis
- d. growth
- e. homeostasis

- ____ 146. A process found only in producers
- ____ 147. Most organisms exhibit this characteristic, which tends to buffer the effects of environmental change
- ____ 148. The capacity to acquire, store, and use energy
- ____ 149. Process in which one generation replaces another

Answer questions 150 – 154 in reference to the five kinds of species interactions listed below. Answers can be used more than once.

- a. competition
- b. predation
- c. mutualism
- d. commensalism
- e. parasitism

- ____ 150. The relationship between a dog and a wood tick is this kind of relationship.
- ____ 151. The interaction between termites and the cellulose-digesting protozoans in the termite gut is this kind of relationship.
- ____ 152. This is the likely interaction between two closely related species of woodpeckers that live in a temperate forest.
- ____ 153. If a wasp lays its eggs inside the larva of a fly, the type of interaction is this.
- ____ 154. When a tropical bird places its nest in association with a wasp nest on the same tree, the type of interaction is this.

Answer questions 155- 160 in reference to the five trophic categories of an ecosystem listed below.

- a. producer
- b. herbivore
- c. carnivore
- d. decomposer
- e. detritivore

- ____ 155. This is a primary consumer.
- ____ 156. A Venus flytrap plant obtains its nitrogen when it functions somewhat like one of these.
- ____ 157. Most mushrooms function as this.
- ____ 158. A bear feeding on a salmon is functioning as this.
- ____ 159. A bear feeding on blueberries is functioning as this.
- ____ 160. An earthworm functions as this.

APPENDIX B

STUDENT CLICKER INTERVIEW QUESTIONS

Read aloud, prior to asking questions: “Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.”

1. Do you think there was an advantage in using the student response clickers in biology class? Why or why not?
2. Do you think there was a disadvantage in using the student response clickers in biology class? Why or why not?
3. What types of questions on the student response clickers did you find to be most effective in helping you study for the test? Why?
 - Multiple choice questions
 - True and False questions
4. Do you think the ability to see whether your answer was correct or wrong was beneficial? Why or why not?
5. Was it beneficial to you to have me go over why that answer was correct? Why or why not?
6. Do you think using the clickers was beneficial to improving your test scores? Why?
7. Did you feel more confident taking the exam because of the clickers? Why or why not?
8. Did you feel better prepared to study for the exam? Why or why not?
9. Would this technology be useful in another other class? Which one(s)? Why?
10. Is there anything else you want me to know?

APPENDIX C

CLICKER STUDENT SURVEY

Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at any time. Your participation or non-participation will not affect your grade or class standing.

Please circle the correct answer.

What is your biology period?

Period 1

Period 3

Period 10

Using the scale, please answer the questions below by circling the appropriate in response to the statement.

5 – Strongly Agree 4 – Agree 3 – Neutral 2- Disagree 1- Strongly Disagree

1. The clickers helped me better prepare for the chapter test.

5 4 3 2 1

2. The clickers helped me better review the material presented in class.

5 4 3 2 1

3. The clickers helped me better prepare for the quizzes.

5 4 3 2 1

4. It was good to get immediate feedback on the clickers so that I could better understand the material.

5 4 3 2 1

5. I paid better attention to lecture when clickers were used.

5 4 3 2 1

6. The clickers helped me better stay focused during the lecture.

5 4 3 2 1

7. The clickers had a significant impact on my participation in biology.

5 4 3 2 1

8. The clickers had a significant impact on my achievement in biology.

5

4

3

2

1

9. What did you like about the clickers?

10. What did you dislike about the clickers?

11. Would you like to see the clickers used in another class? Why?