WHAT IMPACT DO STUDENT-LED DEMONSTRATIONS VERSUS TEACHER-LED DEMONSTRATIONS HAVE ON THE RETENTION RATE OF AP BIOLOGY STUDENTS?

by

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July 2011
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ABSTRACT

In this investigation strategies were implemented with the purpose of improving student engagement and learning in the biology classroom. I investigated whether or not a student-led demonstration versus a teacher-led demonstration had an impact on the retention rate of AP biology students. A progressive Bloom’s Taxonomy technique was used in accordance with a student-led demonstration. I believe that because of the student-led demonstrations and a progressive Bloom’s Taxonomy technique, students reached a higher level of Bloom’s Taxonomy, became self-sustained critical thinkers, and in turn supported their own higher level thinking. This led to an understanding of a topic and long term memory recognition. The participating student had a positive affect on him/herself, the teacher and also my colleagues.
INTRODUCTION AND BACKGROUND

Project Background

Teaching Experience and Classroom Environment
The sampling came from 12 students in AP biology who all elected to take this class. The class ran from 7:20AM to 9:05AM and was valued at 2 credits. The class was made up of three seniors, one male and two females, and nine juniors, four males and five females. No student had free and reduced lunch. All students were predominately Caucasian.

School Demographics
For the past four years I have been teaching at Glacier High School in Kalispell, MT and have taught numerous science subjects: Earth Science, Biology, AP Biology, Chemistry, and Physics. Students came from all over the Flathead Valley. Six valley schools filter into Glacier High School. Our school had a free and reduced lunch population of 30%. The school population was 1400 and the majority of students were Caucasian.

Research Topic
In the next few paragraphs I discuss why I chose the research topic. I also explain my research topic and tell why the topic is significant to me and to my students, administrators, other teachers, and parents. Finally, I include a formal statement of my research purpose.
Some of my observations over the years utilizing both grades and student behavior, showed most students are not capable of asking higher level cognitive questions and do not recognize their misunderstanding of topics. I use these observations and ask the question, how can I foster students to become active and responsible learners in a student-centered classroom, and show them how to ask higher level cognitive questions? Another observation has been that most students are not motivated in the science classroom. I wanted to know how I could engage students in their own learning with a direct relationship between student achievement and student involvement.

In this investigation strategies were implemented with the purpose of improving student engagement and learning in the biology classroom. I investigated whether or not a student-led demonstration versus a teacher-led demonstration had an impact on the retention rate of AP biology students. A progressive Bloom’s Taxonomy technique was used in accordance with a student-led demonstration. I believed students reached higher levels of Bloom’s Taxonomy, became self-sustained critical thinkers, which in turn supported their own higher level thinking.

I have been teaching science for seven years and have noticed that students’ needs out-weigh their own responsibility in the classroom. Students want to memorize answers given to them and do not take the time to internalize the information. In my experience, most students are not capable of asking higher level cognitive questions and do not recognize their misunderstanding of topics. Without realizing it, most students are not motivated in the classroom. Students look upon the teacher to do most of the work and in turn are passive learners. The teacher works harder than the student. I wanted to change
that reality and atmosphere and foster students to become active and responsible learners in a student-centered classroom. The teacher must actively engage students in science and show them how to “do” science. Engaging students in their own learning will not only affect the student, but the teacher and also my colleagues. If students stay active and participate in their own learning, it will not only affect how they comprehend the material, but also how the teacher progresses through the material and how other teachers set the tone in their own classrooms.

Administrators, other teachers, students and parents all benefit from students learning how to actively engage in their own learning and become responsible learners. First, administrators will come to find that test scores and overall grades will increase due to the fact that students have taken responsibility for their own actions and their own learning. Nicholas Athanassiou (2003) addressed the problem that students do not have the ability to frame interesting questions. They do not have the framework to build upon their own thinking, nor do they have the responsibility for their own learning (Athanassiou, 2003). Teachers will be able to help students go above and beyond in the classroom and challenge students to become better learners and be able to comprehend what they are learning. Students will be able to use Bloom’s Taxonomy to promote their own learning of higher level thinking and will have the confidence in knowing how to present a demonstration in front of a group of people when they finish the methodologies of this AR project. Students will be able to employ this higher level thinking and learning in the future. Finally, parents will be able to push their children to higher level thinking orders as students progress through the material and are engaged in their own learning.
Parents will find that their students are active in school and are learning the essentials for life.

**Focus Question**

The Primary question I wish to ask in my Action Research is: What impact do student-led demonstrations versus teacher-led demonstrations have on the retention rate of AP biology students?

The sub-questions I wish to answer in my Action Research are:

1.) How will teacher-led demonstrations affect the retention rate of AP biology students?

2.) What impact do student-led demonstrations have on the student audience in terms of retention rate?

3.) What impact does the student demonstration have on the demonstrator themselves?

4.) What impact do the student-led demonstrations have on the teacher?

5.) How will using Bloom’s Taxonomy in student-led demonstrations and teacher-led demonstrations affect the long term retention rate of students?

**Support Team**

My support team consisted of three teachers from Glacier High School in Kalispell, MT. I work with these professionals everyday and see what great people they are and how they care about their profession and also their students. I depended on them to help me solidify my AR project and effectively change the way I teach.
The first person I chose is a math teacher that received his Masters degree in Administration from MSU Bozeman. This person teaches AP Statistics and Algebra 2. He is a highly qualified member and was able to give information and feedback on the statistics of my AR project. He has also been through a master’s program, so he gave advice on how to write my final paper.

The second person is an English teacher that has worked for three different school districts over 22 years, and has been teaching upper level English for 20 years. This person also volunteered to read one of my papers in EDCI 505 and was a tremendous help. She is especially reliable and is not afraid to give advice and correct grammatical errors. She also has a way of asking questions that helped lead me to a wonderful final product.

The last person I chose has been a math and physics teacher for our school district for 20 years. He is a very dedicated and thoughtful person. He goes out of his way to help others and strives for perfection constantly. He has been the department head for science the last three years at Glacier High School and has done a tremendous job. He is a person that you can always count on and that will spend time to make sure all understand and feel confident about the choices they have made.

I understand that these people are committed in taking the time to assist me in the journey to my final product, so I had open communication with them at all times. The team members all have families and are all coaches, so their time is limited. I needed to make sure I planned each meeting with them in advance and made sure I had submitted my papers and proposals to them at least three days in advance. I contacted them each
once a week and showed them what my next step in the AR project was and how I planned to go about it. In addition, I let them know what their job was and how they could help. Working at the same school was beneficial. E-mail, telephone, and just simply stopping into their classroom to touch base with them was quite easy.

I chose three people that assisted me in writing my AR paper and they gave genuine advice. They are all of different disciplines in the high school, which helped with the overall position of my work. I am lucky to have such wonderful people to work with.

**CONCEPTUAL FRAMEWORK**

**Introduction and Background**

In this investigation strategies were implemented with the purpose of improving student engagement and learning in the biology classroom. I investigated whether or not a student-led demonstration vs. a teacher-led demonstration allowed for students to reach higher levels of Bloom’s Taxonomy, become self-sustained critical thinkers, and this leads to an understanding of a topic and long term memory recognition. A progressive Bloom’s Taxonomy technique was used in accordance with student-led demonstrations. This allowed for the presenting student and the observing students to support their own higher level thinking.

In the following paragraphs I included research studies whose findings provide direction for this investigation. The studies present ideas and a framework for my AR project and give insight into data collection methods. The research includes findings of
Bloom’s Taxonomy and also shows that long term memory and the use of lower level to upper level cognition can affect how a student learns and remembers information.

Findings That Provide Direction

In the following paragraphs I provide two articles that deal with active learning, student-centered classrooms, and Bloom’s Taxonomy. They show how students became more motivated in their learning and were able to reach higher levels of cognition. In addition, I show how I relate my AR project to their findings.

First, students do not have the ability to frame interesting questions. They do not have the framework to build upon their own thinking, nor do they have the responsibility for their own learning (Athanassiou, 2003). He worked with a student population of undergraduates in the Business Studies Department at Assumption College, Worcester, Massachusetts. The students were middle to upper-middle-class traditional students. The focus of this study is to suggest uses of Bloom’s Taxonomy in a scaffolding pattern, to discover the effects on student achievement, and to give teachers ideas of how to use this tool to empower students to be self-responsible learners in the classroom (Athanassiou, 2003). The goal was to “measure the effect of using Bloom’s Taxonomy as a feedback mechanism in an effort to build our students’ critical-thinking skills” (Athanassiou, 2003, p. 544).

The results of the study showed that “Students responded positively to the instructor’s emphasis of Bloom’s Taxonomy of cognitive development and subsequent instructor evaluation using the taxonomy” (Athanassiou, 2003, p. 549). Students seemed to really like the idea of using Bloom’s Taxonomy in the classroom to help improve
critical thinking skills. One student said: “It’s the key to letting the professors know that I get the ideas and am thinking,” while another student stated: “It’s like a roadmap for above-average papers” (Athanassiou, 2003, p. 549). The results supported the observation that Bloom’s Taxonomy can be used to encourage self-assessing, self-responsible learning behavior. This is a practical tool that students can use on their own to reach those higher order levels in cognition. This also supports a student-centered classroom. Also noted from the American Association for Higher Education in 1998: “We are reinforcing our collective realization that learning is a search for meaning by the learner – constructing knowledge rather than passively receiving it, shaping as well as being shaped by experiences” (Athanassiou, 2003, pp. 549-551).

I have related this article to my own project by following the concept that Bloom’s Taxonomy is a way to make students responsible for their own learning and actually feel comfortable with their understanding of the topic. My students understood concepts using higher level thinking and were able to evaluate their own ideas as well as the ideas of others. I implemented Bloom’s Taxonomy into the student-led demonstrations, and my students took away more understanding, thus having greater long term recognition of the topic. Based upon the previous findings, student-led demonstrations are more effective than the teacher-led demonstrations because of the student-centered activity and active learning it lends itself to.

Another interesting article addresses the problem of students and their active participation in the classroom. Active classrooms, which use labs, are better than traditional teaching styles, which use standard resources ordinarily available to the
teacher, such as worksheets. They proved that active learning in the classroom increased the cognitive level of the student as well as created a positive attitude and behaviors in the classroom. “This leads to increased student-centered instructional practices as well as enhanced content knowledge and process learning for students. The goal is to increase critical thinking skills and problem solving skills by posing and investigating relevant questions whose answers must be discovered” (Taraban, Box, Myers, Pollard, & Bowen, 2007, pp. 960-961).

The analysis of the data collected from this experiment showed support for the hypothesis: an overall analysis of test data showed a significant advantage of active learning over traditional learning. Students gained content knowledge when traditional teaching was enforced, but when learning was active, students gained an understanding in laboratory methods and higher level thinking orders. Also, teachers shifted their behaviors toward student-centered learning when using the active-learning curriculum. Teachers and students did have to change their ways of thinking and behaviors when faced with the active-learning curriculum (Taraban et al., 2007).

I used this information to enforce the fact that student-led demonstrations allowed for students to gain more understanding of the topic presented rather than a teacher-led demonstration. Students were actively learning and engaged when presenting the demonstration to the class. Students in the audience were engaged by taking notes and asking questions. This showed responsibility for their own learning and created situations for engagement in Bloom’s Taxonomies higher levels. “Young students must develop an appreciation for the complexity of the world around them. Not all students
are bound for post-secondary science programs, but nonetheless, need to comprehend the process and nature of science, its benefits, and its limitations, in order to participate as responsible citizens” (Taraban et al., 2007, p. 976). I used this statement to encourage my students to think critically and use Bloom’s Taxonomy when presenting their student-led demonstrations and when incorporating information they have listened to through the student-led demonstrations. I wanted my students actively participating in class through the demonstrations. Asking questions and coming up with ways to evaluate the information presented, assisted in making students responsible for their own learning. I was able to prove in my AR project that students can reach to greater heights and have better long term memory recognition of topics based upon the methods listed above.

Athanassiou (2003) and Taraban et. al (2007) have provided evidence that active and student-centered classrooms are where students learn the most and are able to become responsible for their own learning. They understood how to learn and were able to reach the higher levels of comprehension through Bloom’s Taxonomy and through their engagement in classroom activities.

Theoretical Article

In the next paragraphs, I show that Pungente and Badger (2003) will give great interpretation to my AR project through their understanding of teaching Bloom’s Taxonomy. They provide evidence that students can learn how to ask upper level questions and thus connect their understanding of a topic. They also show that students can become active learners through the use of Blooms’ Taxonomy.
Students enter introductory organic chemistry thinking that it is going to be the hardest class they have ever taken. The article shows that by changing the mind set of students by teaching them an effective way to study and ask questions, they do not fear organic chemistry. Students are shown how to fit new material into their mindset and the framework they already possess. Students are taken beyond the knowledge and comprehension levels of Bloom’s Taxonomy. By showing students how to see connections in reactions in organic chemistry, it shows them how to use the upper levels of Bloom’s Taxonomy. When students finally understand how to see and make the connections by themselves, they are no longer just using knowledge and comprehension levels; they are ascending to the synthesis and analysis levels. “[It] is an empowering experience for students. As empowerment replaces the fear, student confidence grows.” (Pungente & Badger, 2003, p. 779).

The study showed that the introductory organic chemistry students would be tested upon all 6 levels of Bloom’s Taxonomy, and that it was in their best interest to look for patterns between reactions and start to develop their “mental framework” when studying organic chemistry. Students appreciated the guidance and also realized that there was literature research behind what he was asking them to do, thus they responded to his concern of teaching them at higher thinking levels (Pungente & Badger, 2003, p. 780).

The results were promising. Student self-confidence increased and awareness of understanding the concepts, rather than memorizing the content, proved effective. Students also gained a great sense of ownership towards the material and became excited
about organic chemistry. They did not fear it anymore nor did they consider it the hardest class they will ever take (Pungente & Badger, 2003). Students were better able and more equipped to make choices in organic chemistry and learning was improved. When implementing Bloom’s Taxonomy into my AR project, I asked the presenting student to follow Bloom’s Taxonomy when showing their demo in front of the class. I asked that they start out with a knowledge-based form of information and slowly work up to a way to show evaluation of the topic. I also asked the observing students to take notes on the presentation and to decipher where each level of Bloom’s Taxonomy appeared. Next, the observing students were required to ask a question of the presenting student, and it would be graded based on the level of Bloom’s Taxonomy. The short term recognition quiz the next day had one question for all levels of Bloom’s Taxonomy, and the long term unit test showed long term memory recognition of the information.

I used Pungente and Badger’s idea throughout my AR project. I wanted to see the confidence in my students rise in having them challenge themselves to a higher learning level without being scared to do so. I wanted them to have confidence in their abilities to make decisions and conclusions based upon their analysis of a topic. Students presented ideas of Bloom’s Taxonomy and expanded on it throughout the year in AP biology. Students saw what I wanted them to be learning, not through memorization, but through their discovery and evaluation of how all things on Earth interact.

Findings That Provide Help with Methodologies

In the following paragraphs I provided information based upon the methodologies of two articles that go along with the way I implemented my AR project. Dave Oliver
and Tony Dobele (2007) wrote an article titled “First Year Courses in IT; A Bloom Rating” and David F. McCormick and M. Susie Whittington (2000) wrote an article titled “Assessing Academic Challenges For Their Contribution To Cognitive Development.”

The first article held the idea of Bloom’s Taxonomy being a guide to designing a course and that it can be used to calibrate assessment tasks and to make sure the comprehension levels correlate. The first year in IT (Information Technology) would be used to examine and perfect the lower levels of Bloom’s Taxonomy, while the second year would allow for the higher levels of the taxonomy. Bloom’s rating should increase as the year increases in IT classes. (Oliver & Dobele, 2007). The program maintained that they “expect[ed] the cognitive level of students to improve as they advance through the degree programme (Oliver & Dobele, 2007, p. 348).

The article uses prior studies in IT that used Bloom’s Taxonomy and computes a Bloom rating for the course. Five hundred-forty-seven course questions were assessed and all related to Bloom’s Taxonomy and were given a Bloom Level 1-6. A Bloom’s rating was given to each course that used the questions by taking the mean value obtained by multiplying the Bloom level of each question by the weight allocated to it. The weight depended on the assessment given, such as assignments were worth 40%, examinations were worth 60%, and the overall was 100%. A final score was then calculated and statistics showed which courses had promising results.

The results did not show that in the first year alone students gained just knowledge and comprehension using Bloom’s Taxonomy; students gained continuously through the higher levels of the taxonomy within one year. “We still maintain that
courses should exhibit a rise in Bloom rating as they move downstream, since we expect the cognitive capabilities of students to improve as they advance through the degree programme.” (Oliver & Dobele, 2007, p. 357).

I used the Bloom rating in my AR project. I liked the idea of labeling each level of Bloom’s Taxonomy from the lowest to the highest and numbering them 1 through 6 respectively. This was used when grading the presenting student on his/her demo and also when the observing students took notes and asked questions. Their grade reflected what level of Bloom’s Taxonomy they used in the presentation, notes, and questions. This allowed me to effectively assess their understanding of the material and what level they were on in terms of cognition. In the end, I was able to relate this information with the students’ understanding of the topic and their short and long term recognition of the topic presented.

The next article addressed details of data collection. “Undergraduate instruction should focus not only on providing students the content knowledge of their chosen discipline, but also on facilitating the development of students’ critical thinking skills.” “The focus of the study was to use Bloom’s Taxonomy to examine the academic challenges provided to students.” (McCormick & Whittington, 2000, p. 114). Students were rewarded with grades based on their cognitive levels. Since Bloom’s Taxonomy is a hierarchal system, therefore, it was important to note that students were graded on their use of higher cognitive levels.

Eleven faculty members were used from nine departments/schools within the college. Each participant provided copies of their academic challenges used in the
course. Each challenge was categorized by activities, problem sets, written reports, presentations, laboratory tests, quizzes, midterms, and finals. Each task and question was analyzed to determine the cognitive level and the challenge it provided for the student. A data collection worksheet was kept using the levels of Bloom’s Taxonomy, cognitive levels, and the degree to which the challenge related to the students’ course grade. A number corresponded to the level of Bloom’s Taxonomy was used and ranged from 1 to 6. “To obtain the grade-weighted cognitive distribution, the initial cognitive distribution for each academic challenge was multiplied by its value to the student’s final grade.” (McCormick & Whittington, 2000, p. 116).

The results proved successful, although they varied based upon the type of academic challenge. “It proved that well developed academic challenges can contribute to the development of students’ thinking skills.” (McCormick & Whittington, 2000, p. 120).

It was difficult using McCormick & Whittington’s idea and academic challenge for my AR project. But, I stayed true to the measuring system of using Bloom’s Taxonomy rating scale of 1-6 based upon what the student used in their presentation, notes, and questions. I also made sure I challenged the students by using all levels of Bloom’s Taxonomy in my quiz and unit tests. The ratings corresponded to the level of cognition and short vs. long term memory recognition.

Oliver & Dobele (2007) and McCormick & Whittington (2000) had similar ideas using the Bloom’s Taxonomy rating system and weighing the academic challenges in
order to receive the student’s grade. I, however, only used part of the idea in my AR project to keep it simple and maintain accurate results.

**Findings That May Provide Help In The Future**

In the following paragraphs I will give an explanation of ideas that will be helpful for the future. One particular article gave insight into Bloom’s Taxonomy and how it related to students. While, the second article showed how students that were engaged in the learning process prospered and gained long term memory recognition.

The first article studied the effects of graduate level courses and the congruence of Bloom’s Taxonomy. The study included uses of Bloom’s Taxonomy with the World Wide Web. “The goal of the course is to help new students acquire information about the historical and theoretical foundations of the Instructional and Performance Technology Department at Boise State University both on-line and on-campus courses leading to a master’s degree” (Chyung & Stepich, 2003, p. 321). The study population was 13 students in each class. Gagne’s “Nine events of instruction” and Bloom’s Taxonomy were put together to create an instructional base for the IT course. Bloom’s Taxonomy was used to make sure there was congruence within each module, or progressive learning criterion, of study. “We used Bloom’s Taxonomy to determine the levels of the objectives for each module and to design learning activities through which students would accomplish those objectives.” (Chyung & Stepich, 2003, p. 323). Before Chyung & Stepich (2003) decided how they would create and administer each module, they had students take a survey, based upon a 3-point scale, to see how much prior knowledge the
students had on the topics that were to be covered in class. Once they got the results from the survey, they then fixed the progressive modules with the levels of cognition based upon Bloom’s Taxonomy. This allowed for students to start with the lower levels and work their way up to the upper levels of Bloom’s Taxonomy and cognition.

This article proved that Bloom’s Taxonomy can be helpful when aligning assessments to cognitive levels to encourage adequate understanding of the topic. Students were also able to monitor their self-learning more effectively and to build a close rapport with the instructor because the students and instructor were on the same page and the students knew what the instructor was asking for in the assessments.

I used Chyung and Stepich’s (2003) ideas and aligned my quiz questions and unit test questions with Bloom’s Taxonomy to see if there was a higher short or long term memory recognition of the topic being studied. When students presented their demonstrations to the class, this was the first time students had been exposed to the information, and I wanted to prove that the demonstrations helped solidify information and created long term recognition. I also gave students a pre and post-test using the same test throughout the unit. This provided quantitative feedback and helped prove there was progress of understanding.

The second article discussed the fact that students have a higher rate of long term memory when students learned to do labs at home and discussions and analyses at school with their teacher. Allowing students to do labs at home showed that students would take more chances and risks, thus supporting Flinders’ (2009) point that students would understand the process of labs better if they had to do them on their own. Flinders did
help with the data analysis at school so students would recognize patterns in their data and then be able to come to some conclusions on their own. The inquiry process was a way to forgo the lower levels of Bloom’s Taxonomy, yet come back to them in the middle of the assignment and discuss all applications using the lower levels and upper levels of the taxonomy. The population used was 16 students, a mix of 56% male students and 44% female students. They were predominately middle class Caucasians (Flinders, 2009).

The second article also proved the capstone to be successful. He used a teacher prompt everyday to make sure he was keeping track of his ideas and feelings based upon his treatment or study. I used something similar in my AR project to see the effects on the teacher. A pre and post-test and student surveys gauged how students were progressing. The article explained how the author measured the percentage change from the pre and post-test to show long term memory. I found this interesting and used this in my AR project. A triangular matrix was also used to collect data, which I saw fit for my AR project as well.

Chyung, Stepich (2003) and Flinders (2009) both showed that long term memory and the use of lower level to upper level cognition can affect how a student learns and remembers the information. It also showed how students effectively used the information to form ideas and evaluations. I proved these similar ideas in my AR project and proved that long term memory improved based upon the method used when teaching the topic.
Major Findings of the Literature

There are several themes to the literature review. I have described the major findings of the literature in the next few sentences. The research includes findings of Bloom’s Taxonomy and also shows that long term memory and the use of lower level to upper level cognition affects how a student learns and remembers information. Active and student-centered classrooms are where students learned the most and became responsible for their own learning. Through Bloom’s Taxonomy they understood how to learn and were able to reach higher levels of understanding through their engagement in classroom activities. Students also gained a great sense of ownership towards the material and became excited about learning. They did not fear it anymore. Students were better able and more equipped to make choices, and learning was improved.

METHODOLOGY

In the following paragraphs I outline the methods that were used for my AR project. I discuss the treatment, research design, and lead into how the data was collected for analysis. The goal was to show that through data analysis, I confirmed that students did receive lower grades in Ch.7, the non-treatment, versus Ch.8 using the treatment of teacher-led demonstrations versus student-led demonstration and Bloom’s Taxonomy. The treatment was also implemented into Ch. 12, and similar goals were reached.

The treatment was spread out through a 2 month period and administered to 12 junior and senior students in AP Biology (See Appendix A and B). The treatment and research design took place in Glacier High School (GHS) in Kalispell, MT. Thirty percent of
students were on free and reduced lunch at Glacier High School. This statistic was under-represented based on the reference used, the GHS principal. It is widely accepted that high school students did not want to acknowledge that they may be in need of assistance. The sampling came from twelve students in AP biology who all elected to take this class. The class ran from 7:20AM to 9:05AM and was worth 2 credits. No student had free and reduced lunch, and the students were predominately Caucasian. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained.

The textbook information came from AP Edition Biology by Campbell and Reece (Campbell, & Reece, 2008). The AR project was divided into three sections, each using one of the chapters in the book. The chapters chosen were all in Unit 2 “The Cell.” Chapter 7 is titled “Membrane Structure and Function”, Chapter 8 is titled “An Introduction to Metabolism”, and Chapter 12 is titled “The Cell Cycle.” Chapter 7 was taught as usual and there was no treatment involved, I just collected data. Chapter 8 had sections 8.1 – 8.4 being non-treatment design sections and section 8.5 incorporated the treatment being a teacher-led demonstration. Chapter 12 also included the treatment and students performed demonstrations.

Treatment

In Chapter 7 there was no treatment involved. Students first took a pre-test to gauge where their abilities lied in terms of knowledge of content and Bloom’s Taxonomy (See Appendix C). Bloom’s Taxonomy was not used in the demonstration, yet the students
did not know this piece of information. The teacher then presented a demonstration and students took their own style of notes. Ch.7.1 demonstration was titled “Membrane proteins and their function.” This was a quick demonstration dealing with proteins such as integral proteins, peripheral proteins, transmembrane proteins, and integrins and how they are arranged within the fluid mosaic model. A membrane is a collage of different proteins embedded in the fluid matrix of the lipid bilayer and each protein has a specific job, function, and location within the bilayer. The teacher created a model made out of Jell-O and inserted different candies within the Jell-O lipid bilayer to represent each type of protein. The job, function, and location of each protein were discussed in class.

The second demonstration was presented by the teacher as well and incorporated Ch.7.4. A model was created out of Styrofoam and demonstrated; first, how ions maintain membrane potential with a proton pump second, demonstrated cotransport: active transport driven by a concentration gradient and third, showed the sodium-potassium pump, a specific case of active transport.

A six multiple-choice question quiz was then administered after the teacher demonstrations and had one of each of the levels of Bloom’s Taxonomy on it (See Appendix D and E). The purpose of the quiz was to see what level of Bloom’s Taxonomy students comprehended. The teacher could then tell how well the students understood the demonstration along with the content. This was a valid and reliable instrument used by Oliver & Dobele (2007), McCormick & Whittington (2000), and Chyung and Stepich (2003).
Chapter 8, where the treatment first took place, was prefaced with information about Bloom’s Taxonomy and how to present a demonstration in front of the class (See Appendix F). Students had a chance to practice figuring out which level of Bloom’s Taxonomy was being asked in multiple choice questions. The levels of Bloom’s Taxonomy in order from easiest to most difficult are: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Chapter 7 post-test (See Appendix C) students took previously was used to practice figuring out what level of Bloom’s Taxonomy was asked in the multiple-choice test question. Students were able to analyze the difference in the types of Bloom’s Taxonomy questions. Knowing the levels of Bloom’s Taxonomy allowed students to take control of their own learning and become self-sustained critical thinkers (Athanassiou, 2003). This is a reliable test used by Athanassiou. The first part of Ch.8, sections 8.1-8.4, was taught using the non-treatment, where Bloom’s Taxonomy and a teacher-led demonstration prevailed (See Appendix G). The second part of Ch.8, section 8.5, was taught using the treatment and Bloom’s Taxonomy was used along with a teacher-led demonstration titled “Modeling: Induced Fit in a Multienzyme Complex” (See Appendix H) (Killough, 2010).

For the final part of the AR project, each student presented a demonstration on a topic within Ch.12. The criterion for the demonstration was based upon the treatment (See Appendix I). Students led a demonstration in front of the class and were asked to incorporate all levels of Bloom’s Taxonomy while presenting the information. This served as a way to compare teacher-led demonstrations versus student-led demonstrations and use the data collection instruments to see there was a difference in content knowledge
learned and retention rate. Athanassiou (2003), Taraban et al (2007), and Pungente & Badger (2003) all used similar criteria in order to make students self-responsible learners and actively occupied in their own learning. Students were engaged in critical thinking. Validity and reliability would be based primarily on outside sources with experts in the field.

**Research Design**

The pre and post-tests included all levels of Bloom’s Taxonomy. There were 30 multiple choice questions asked about each chapter throughout the AR project. In order to see if there was long term retention of the information presented from the beginning of the chapter to the end, the pre and post-tests were analyzed. To decide if students were, in fact, doing better on the post-test than the pre-test, the data was analyzed and a percent increase was calculated. Students did better in terms of percent increase, and it correlated with a long term retention rate. A quiz was given in Ch.7, 8, and 12 that determined whether there was a short term increase in content knowledge when comparing the non-treatment with the treatment units using Bloom’s Taxonomy. Furthermore, the data collection instruments are discussed below that describe how content knowledge and retention rate were captured.

In Chapter 7, there was no treatment involved. Students took a 30 question multiple-choice pre-test that incorporated all levels of Bloom’s Taxonomy (See Appendix C). The teacher presented a demonstration from Ch.7.1 and had students take notes on the demonstration titled “Membrane proteins and their function,” where Bloom’s Taxonomy was absent. The student audience had a chance to ask questions about the demonstration.
to make sure they understood it correctly. Next, students wrote down one question they
wanted to ask the presenter about the demonstration, but perhaps did not ask or were too
shy to ask during class. Students then wrote down their “Muddiest point” on a pre-made
“Muddiest point” card. The “Muddiest point” cards were read by the teacher and a
presentation over the “Muddiest points” was given to the students the very next day. The
presentation addressed all “Muddiest points” and allowed time for students to ask
questions. Students had a chance to hear their questions answered before they took a six
question quiz over the information that was presented to them the day before. The six
multiple choice question quiz had one of each of the levels of Bloom’s Taxonomy on it,
yet students were unaware of this feature. The purpose of the quiz was to see what level
of Bloom’s Taxonomy students comprehended and how much students increased on their
content knowledge. This also served as a short-term test. It was less than two days
between the information and the quiz.

Next, the teacher presented a demonstration from Ch. 7.4. The demonstration was
made out of Styrofoam and showed membrane potential, co-transport and active
transport. Similar steps were followed as listed in the previous paragraph where Bloom’s
Taxonomy was incorporated into the quiz, but not the demonstration. This helped serve
as a standard of measurement for short term recognition.

After that, students took a Ch.7 post-test that was the same as the pre-test.
Comparing the pre and post-test showed the retention rate of the students. This was
considered a long term test. This test did not take place the day after the quiz, but
occurred when the class finished other assignments and lectures in Chapter 7. In
conclusion, I asked students to answer a survey of what they liked or disliked about the demonstrations and the other methods used during this chapter (See Appendix J).

Finally, I filled out a teacher journal along the way with special prompts in order to remember how I was feeling during this time (See Appendix K).

Chapter 8 consisted mostly of the same items and in the same order as chapter 7. First, Chapter 8.1-8.3 was lectured and a few tasks were assigned. During Chapter 8.4 the teacher presented a demonstration titled “Toothpickase Activity,” similar to Chapter 7’s, non-treatment, presentation and outline (See Appendix G). Students followed the same procedures as in Chapter 7. Chapter 8.5 was different. In order to keep this a random study, chapter 8.4 followed the non-treatment way of presenting demonstrations and chapter 8.5 followed the research design using the treatment. This is where the research design began to compare Ch.7 with Ch.8. Throughout Chapter 8.5 the teacher presented a demonstration that spoke to all levels of Bloom’s Taxonomy and also correctly presented the demonstration, titled “Modeling: Induced Fit in a Multienzyme Complex” (See Appendix J) (Killough, 2010). Students followed procedure and took Cornell notes on the demonstration. (Cornell notes are a way of representing information in an ordered manner. First, a person writes down notes they take in a big box that takes up most of the paper on the right hand side. Second, a person pulls out the important information from the big box such as dates, places, main ideas, and writes them to the left of the big box. Last, a box at the bottom of the page of notes is where a summary can be written about the notes taken on that page. This allows for a person to quickly review their notes and remember what information was presented.) Students also wrote down a
question dealing with the demonstration and finished with writing their “Muddiest point.”

Students were graded upon the questions that were asked about the demo in terms of the level of the Bloom’s Taxonomy. They received a 1 for a knowledge question, a 2 for comprehension, a 3 for application, a 4 for analysis, a 5 for synthesis, and a 6 for an evaluation question. The next day the teacher went over the “Muddiest point” cards and answered the student’s questions. Students then took a 6-question multiple-choice quiz using all levels of Bloom’s Taxonomy to check for content knowledge of the topic that was presented. Chapter 8 was finished up using a few other means of learning and doing labs and finally, students took their post-test. After students took their post-test, they were asked to fill out the same survey as they did for Ch.7. The teacher also filled out a journal, recording information that happened along the way.

Chapter 12 was similar to Ch.8.5 in terms of the treatment; however, students were to present the demonstration to the class while using all levels of Bloom’s Taxonomy instead of the teacher. Students followed a set of criterion while presenting their information (See Appendix I). Students made sure they were presenting using good technique. They performed the demonstration instead of the teacher, and all other criteria of the treatment were met and were similar to Ch. 8.5.

Next, I will explain the data analysis and interpretation for the pre and post-test for Ch.7 and Ch.8 and then Ch.12 that was given to my AP Biology students. Twelve AP Biology students were each given the pre-test of 30 multiple choice test questions for Ch. 7 and Ch. 8 (seven females, one with an A in AP Biology, three with a B, two with a C, and one with an F and five males, one with a B and four with D’s.) This test was graded,
and a percent of how many questions were correct, and the grade earned was recorded. As listed above in previous paragraphs, students transitioned through the different forms of assessment and research design. After two weeks, students took the post-test. The post-test was the same test as the pre-test, so they were easily compared. The post-test was graded the same as the pre-test and the percent of correct questions was recorded. After all data was gathered for the pre and post-test for Ch.7, 8, and 12 the data showed how the research design improved my student’s scores on the post-test, thus showing an increased retention rate.

**Sampling Strategies**

Nine data collection instruments were administered and the information was collected each time a demonstration was presented in class. The instruments were: pre-test, Cornell notes, audience question, muddiest point, quiz, demonstration, post-test, student survey, and teacher journal. The data collected was kept in Excel spread sheets in conjunction with a program called Fathom. In the next few paragraphs each data collection instrument is discussed in terms of the sampling strategy.

The first methodology is the pre-test that each student took before entering into a new unit (See Appendix C, L and M). It was created using the AP Edition Biology by Campbell and Reece Test Generator. Twelve AP Biology students were each given the pre-test of 30 multiple choice test questions for Ch. 7, 8, and 12 (seven females, one with an A in AP Biology, three with a B, two with a C, and one with an F and five males, one with a B and four with D’s.) Each of the 6 levels of Bloom’s Taxonomy questions was represented throughout the test. This served as background information and allowed me
to gage each student’s cognitive level and their previous knowledge on the unit that proceeded. I received 12 grades based upon the pre-test and was able to compare the data to a similar post-test to measure retention rate of students. I used this method on each of the three units throughout the Action Research project.

The second data collection instrument was observing students’ Cornell notes they took throughout each of the three units (See Appendix N). The first unit, Ch.7, students took their own notes in any fashion they wished, and these were graded upon completion. Yet, I recorded personal notes to see how many levels of Bloom’s Taxonomy they used in their writing. Only in the second (Ch.8) and third units (Ch.12) did students have a standard note taking procedure (Cornell notes) that prompted them to write down their thoughts and answers on how the presentation displayed each of the Bloom’s Taxonomy levels (See Appendix N). It assisted in their understanding of the concepts presented.

The observing students were asked to write one question they would like to ask the presenting student or presenting teacher. Students were engaged in the learning process by taking notes and writing down one pertinent question. This question was scored using the Bloom’s rating scale 1-6 (Oliver & Dobele, 2007). This score was kept on an Excel grading sheet and allowed me to see the cognitive level each student was functioning at along with their retention rate. I gave students a completion grade, and recorded data with respect to the Bloom’s rating scale. In unit two (Ch.8) and three (Ch.12) students were graded with the Bloom’s rating scale.

The Classroom Assessment Technique (CAT), “Muddiest Point”, was also used to give data as to what the observing student did not understand about the demo (Thomas &
Cross, 1993). This was recorded as qualitative data and placed in a Word document and
an Excel spread sheet. Throughout all three units, the “Muddiest Point” gave evidence as
to what concepts students did not understand and what the presenting student or the
teacher did not explain thoroughly. I used this information and recorded it in my teacher
journal and applied it towards teaching the rest of the unit.

After the presentations, both teacher-led and student-led, all students were asked
to take a progressive 6-question quiz based upon all levels of Bloom’s Taxonomy (See
Appendix D, E, F, O, P, Q, and R). This quiz took place the day after the presentation.
Details from the records proved short term recognition of the demonstration, and served
as evidence of higher level thinking. For each of the three units, grades were taken based
upon the Bloom’s rating scale.

During Ch.12, the presenting student allowed me to proof their information, so I
could approve it before they presented it to the class. In addition, the students had certain
criterion that must be met during the presentation and were graded on their presentation
(See Appendix I). Students presented all levels of Bloom’s Taxonomy throughout their
presentation and showed where the levels occurred. Lastly, this was graded using the
Bloom’s rating scale 1-6. I collected 12 presenting student’s grades and documented it
on an Excel grading sheet.

The seventh data collection instrument was the post-test and was given at the end
of each unit. A similar pre-test was given before each unit and was compared to the final
unit test. Each of the 6 levels of Bloom’s Taxonomy questions was represented within
the test. This confirmed each student’s cognitive level and their retention rate on the unit as the two tests were compared.

Qualitative data was collected using a student survey and served as the eighth data collection instrument (See Appendix J). Students were asked to voluntarily fill out a 12 question survey based upon their thoughts and ideas of how chapter seven, eight and twelve went respectively. The survey was administered after each post-test. The goal was to see if students thought there was a difference between the chapters and if their learning style changed throughout the non-treatment versus treatment units. I wanted to see if students noticed that they felt they learned the material of a particular chapter better and if that correlated with the treatment or non-treatment chapter. Knowing what my students’ thoughts and feelings were on presenting demonstrations, gave me insight in deciding if this research project helped students in any way. Did students learn the material better if students were presenting the demonstrations versus the teacher presenting the material? Did using Bloom’s Taxonomy help students learn content and help with retention rate? I also asked when the turning point was when they started to fully understand the information in the unit; what helped them the most? Lastly, knowing how students felt about the demonstrations and all the data collection instruments, helped me serve my students and enabled me to find ways that they learned best. I then knew how students reached higher cognitive levels and a higher retention rate. The information was kept in a Word document.

The ninth instrument was a teacher journal. I filled out my teacher journal after all demonstrations and after every data collection instrument using similar prompts each
time. When looking back at each entry, I was able to see what impact the student-led demonstrations had on the teacher. I compared this to the first unit and other times throughout all three units to how I felt when I, the teacher, presented the demonstration versus how I felt when the students presented the demonstration. I think this treatment and research design allowed for a smooth and successful teaching style in my classroom.

DATA AND ANALYSIS

Pre and Post-Test

In the next few paragraphs I explain the main topic of research and how my data interpretation aligns with the topic. The results from the pre and post-test for Ch.7 (See Appendix C), Ch.8 (See Appendix L), and Ch.12 (See Appendix M) are discussed below. I discuss the data for Ch.7, then for Ch.8, and end by comparing Ch.7 data with Ch.8. Next, I discuss the data for Ch.12 and end that section by comparing Ch.7, Ch.8, and Ch.12 data.

When interpreting Ch.7 (non-treatment) pre vs. post-test comparing means, the standard of error of the mean of Ch.7 pre-test was 3.73 and the standard of error of the mean of Ch.7 Post-test was 4.72 (See Appendix S). The population mean of Ch.7 pre-test was less than that of Ch.7 post-test. The test statistic, students, which is a measure of variance in data, was -2.60 and there were 20.89 degrees of freedom. If it were true that the population mean of Ch.7 pre-test were equal to that of Ch.7 post-test, the null hypothesis, the probability of getting a value for student’s $t$ this small or smaller would be
a p-value equal to 0.0083. This was less than 1%. This provides evidence to support the alternative hypothesis, that there was a difference in means. Students scored higher on the post-test than the pre-test and it was statistically sound. Receiving scores that supported the alternative hypothesis showed the difference between the pre and post-test scores was not a fluke; the teacher implemented something that gave students a chance to increase their content knowledge and long term memory recognition of information.

One example of a question that a student answered differently on the pre-test than the post-test in Ch.7 was:

In order for a protein to be an integral membrane protein it would have to be which of the following?

a. hydrophobic

b. completely covered with phospholipids

c. exposed on only one surface of the membrane

d. hydrophilic

e. amphipathic

This particular student answered C, hydrophilic on his pre-test and answered E, amphipathic on his post-test. Answer E was correct and the student successfully gained knowledge from pre to post-test. This means that the student gained content knowledge and increased in retention rate by studying or using traditional teaching methods.

Next, the interpretation of Ch.7 pre vs. post-test difference of means, showed the standard deviation of Ch.7 pre-test being 12.93 and Ch.7 post-test was 16.35 (See Appendix T). The standard deviation explained that students showed more diversity in
terms of improvement; students were farther apart and not grouped as close on the post-test. This indicated that some students showed more improvement on the post-test than others. Overall, students’ averages were higher on the post-test. Based on the samples and using un-pooled variances, the 95.00% confidence interval for the mean of Ch.7 post-test minus the mean of Ch.7 pre-test was 15.67 +/- 12.52 and thus resulted in a range from 3.15 to 28.19, which were percentage increases. This portrays I am 95.00% confident that the true mean of the differences was in the interval from 3.15 to 28.19. As a result, students did better on the post-test than the pre-test and it was statistically sound. Students did better on the post-test than the pre-test and it might be because of traditional teaching methods.

![Box Plot](image)

*Figure 1. Ch.7 Pre and Post-Test Data, (N = 12)*

Lastly, looking at Ch.7 pre vs. post-test Data (Figure 1), you can see that the data is symmetrical indicating that there was only 1 outlier (73.00%) in Ch.7 pre-test (student #11, male with a grade of a D in AP Biology). This could be an indication that he was a
great test taker or good at guessing on multiple choice tests because his post-test shows that he received a lower grade (63.00%) than the pre-test. It also indicated that there was another reason for a variance in the standard of error from pre to post-test. The box plot showed that all students seemed to be grouped together in the pre and post-test, yet Ch.7 post-test has much higher scores. The results from Ch.7 pre and post-test showed that students did increase in their retention rate from the pre to the post-test. The issue of symmetry with the box plots is really just a criterion that allowed for a t-test to be used with a sample size that is less than 15. As a reminder, Ch.7 was a teacher-led demonstration without incorporating Bloom’s Taxonomy, nor did the teacher show the students how to successfully perform a demonstration in front of the class.

Looking at Ch.8 and knowing there were teacher-led demonstrations with Bloom’s Taxonomy incorporated and used as the treatment, the statistics show students are improving. Chapter 8 pre vs. post-test comparing means, showed the Ch.8 pre-test with a standard of error of the mean of 2.62, and Ch.8 post-test with a standard of error of the mean of 4.55 (See Appendix U). The alternative hypothesis was true; the population mean of Ch.8 pre-test was not equal to that of Ch.8 post-test. The test statistic, students’ t, using unpooled variances, was -5.09. There were 16.13 degrees of freedom. If it were true that the population mean of Ch.8 pre-test were equal to that of Ch.8 post-test (the null hypothesis), the probability of getting a value for students’ t with an absolute value this great or greater would be a p-value of 0.00011. The p-value is very extreme and showed students improved on the post-test in relation to the methods of teaching that occurred in the classroom. Students did better with content knowledge and as a result
were doing better with their long term retention rate of information. One student wrote on their Student Survey that “Bloom’s Taxonomy helped relate the concepts in their mind,” while another student said that “Bloom’s Taxonomy helped them focus in on the kind of question that was being asked on the test.”

Next, Ch.8 pre vs. post-test difference of means, showed that the standard deviation of Ch.8 pre-test was 15.08 and Ch.8 post-test was 9.08 (See Appendix V). The standard deviation was smaller than in Ch. 7, indicating that students were grouped closer together. Based on the samples and using unpooled variances, the 95.00% confidence interval for mean of Ch.8 post-test minus the mean of Ch.8 pre-test was 26.70 +/- 11.12 ranging from 15.59 to 37.82. This portrayed that I am 95.00% confident that the true mean of the differences was in the interval from 15.59 to 37.82.

![Box Plot](image)

**Figure 2.** Ch.8 Pre and Post-Test Data, \((N = 12)\)

Chapter 8 pre vs. post-test data (Figure 2 box plot explains that the data was symmetrical and that there were no outliers. This indicated that students moved together as they increased their retention rate from pre to post-test. The post-test scores were
much higher than the pre-test scores. Students understood information presented in class to a fuller extent. The treatment enabled students to become self-sustained critical thinkers. Students scored higher on the post-test because they thought about the type of question, or level of Bloom’s Taxonomy, being asked on the test and therefore gave a purposeful answer.

Comparing statistics from Ch.7 (non-treatment) to Ch.8 (treatment), the information in the box plots was significant because the sample size was small (12). When comparing means, you must be careful the sample looked like it came from a population that was normally distributed. The sample had little skewness and few or no outliers. The data that I collected followed these rules, thus I compared the means of Ch.7 and Ch.8.

Both Ch.7 and Ch.8 showed that I am 95.00% confident that the true mean of the differences in the interval for pre and post-test were above zero indicating this was an improvement in teaching design in the classroom in some way. Chapter 7 has a 95.00% confidence interval from 3.15 to 28.19 and Ch.8 has a 95.00% confidence interval from 15.59 to 37.82. By comparing these numbers, I could tell that Ch.8, which contained the treatment, had a higher average percent of scores. Also, the change in p-values, Ch.7 = 0.0083 and Ch. 8 = 0.00011, indicated that students were increasing their post-test scores, thus attributed to the change I made in the classroom using my AR methodologies. This showed that the treatment was working and students were improving their retention rate in AP Biology. On average, students scored higher when using their knowledge about Bloom’s Taxonomy and understood the demonstrations that were presented in class.
The interpretation of Ch.12 pre vs. post-test comparing means showed that the standard of error of the mean of the pre-test was 2.34 and the standard of error for the post-test was 3.64 (See Appendix W). The numbers showed that the alternative hypothesis was correct, there was a difference in means. The population mean of Ch.12 pre-test was less than that of Ch.12 post-test. The test statistic, student’s t, which was a measure of variance in data, was -6.15 and there were 18.75 degrees of freedom. The probability of getting a p-value for student’s t this small or smaller would be 0.0001. This was substantially less than 1% and provided evidence to support the alternative hypothesis. This proved students scored higher on the post-test than the pre-test and was statistically sound.

One example of a question that a student answered differently on the pre-test than the post-test in Ch.12 was:

If mammalian cells receive a go-ahead signal at the G\textsubscript{1} checkpoint, they will

a. Show a drop in MPF concentration

b. Move directly into telophase

c. Exit the cycle and switch to a nondividing state

d. Complete the cycle and divide

e. Complete cytokinesis and form new cell walls.

This particular student answered B on the Pre-Test then correctly answered D on the post-test which showed knowledge and comprehension from the pre to post-test. The student used their knowledge of Bloom’s Taxonomy to decipher what level of question was being asked. This level of question was strictly regurgitation. The simple answer
only showed a sequence of events. The student then went through the answers to decide what would make sense in correctly responding to a knowledge or comprehension question. The responsible student did well on the post-test because he was aware of Bloom’s Taxonomy and how to use it to his advantage. The student was active in his own learning. He had the framework of his own thinking and built upon it using Bloom’s Taxonomy (Athanasiou, 2003).

Next, the interpretation of Ch.12 pre vs. post-test difference in means showed a Standard Deviation of the Ch.12 Pre-Test as 8.09 and Ch.12 Post-Test as 12.60 (See Appendix X). A 95.00% confidence interval for the mean of Ch.12 post-test minus the mean of Ch.12 pre-test was 26.58 +/- 9.061 and thus resulted in a range from 17.53 to 35.64. This portrayed I am 95.00% confident that the true mean of the differences was in the interval from 17.53 to 35.64. The sampling process could be repeated and would generate the population differences of means 95.00% of the time.

Figure 3. Ch.12 Pre vs. Post-Test Data, (N = 12)
The appearance of the box plot for Ch.12 showed an outlier (Figure 3). This indicated that this student was well below the mean of the Ch.12 Pre-Test. If this particular student’s pre and post-test were compared it would show a 40.00% increase in knowledge, yet this student was considered to be an outlier. Next, students were grouped closer together and scored lower on their pre-test scores, and scores showed that in the post-test students scored considerably higher than the pre-test.

When comparing Ch.7, Ch.8, and Ch.12, there were several similarities and interestingly enough, differences. First, Ch.7, 8, and 12 all have a p-value that were less than 1.00%, so the null hypothesis of Ch. 7, 8, and 12 pre and post-test each being equal was rejected. This means that students performed better on the post-test in all cases. The p-value for Ch.7 was 0.00083, Ch.8 was 0.00011, and Ch.12 was < 0.0001. Chapter 7, the non-treatment, and Ch.8, with non-treatment and partial treatment, had a p-value that was greater than Ch.12 which included the treatment. In conclusion, the small p-value reinforces the fact that the treatment did work, and it can be attributed to a change in the classroom, it being my AR methodologies. Students did learn better from students performing the demonstrations and using Bloom’s Taxonomy in Ch.12.

The next observable change between Ch. 7, 8, and 12 was the difference in mean on the pre vs. post-test in Ch.7 (15.70%), Ch.8 (23.75%), and for Ch.12 (26.60%). It showed Ch.8 a tenth higher than Ch.12 in the difference in mean increase. Yet, when looking at the mean of Ch.8 pre-test, 29.83, and the post-test, 53.58, and comparing those to the mean of Ch.12 pre-test, 37.75, and the post-test, 64.33, it explained that the means on the pre and post-test started higher in both cases for Ch.12. The statistics displayed
that students were increasing their content knowledge and thus retention rate. Students discovered how to be better self-learners using Bloom’s Taxonomy and student-led demonstrations.

Table 1
Post-Test Correct Answers with Bloom’s Taxonomy, (N = 12)

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Lower Level Bloom’s Taxonomy Questions (%)</th>
<th>Upper Level Bloom’s Taxonomy Questions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 7</td>
<td>68.25</td>
<td>56.48</td>
</tr>
<tr>
<td>Chapter 8</td>
<td>61.59</td>
<td>65.48</td>
</tr>
<tr>
<td>Chapter 12</td>
<td>68.56</td>
<td>53.12</td>
</tr>
</tbody>
</table>

The next difference between Ch.7, 8, and 12 post-test was in the lower level Bloom’s Taxonomy questions vs. the upper level Bloom’s Taxonomy questions (Table 1). In Ch.7 (non-treatment) there was 252 lower-level (Knowledge, Comprehension, and Analysis) Bloom’s Taxonomy questions and 172 total correct answers were given by 12 students. The percent correct for lower-level Bloom’s Taxonomy was 68.25%. For upper level Bloom’s Taxonomy (Analysis, Synthesis, and Evaluation) in Ch.7 there were 56.48% correct answers. In Ch. 7 students did much better on the lower-level questions. If Ch. 7 was compared to Ch.8 (Non-treatment and Treatment), for the lower-level questions there were 61.59% correct answers and for the upper-level there were 65.48% correct. In this unit, students succeeded in the upper-level Bloom’s Taxonomy questions. Chapter 12 (Treatment) showed 68.56% correct for the lower level and 53.12% for upper level Bloom’s Taxonomy. Students did slightly better in the treatment unit than the non-treatment unit in the lower levels of Bloom’s Taxonomy. Students failed to answer the
upper level questions in the treatment unit at a higher percentage than the non-treatment unit. It appeared, in this case, that overall students did better in the lower levels of Bloom’s Taxonomy when Bloom’s Taxonomy and student-led demonstrations were applied to a unit. A factor that could have been involved, simply put, Ch.7 was easier. Typically as the chapters progress in a textbook, they get more complex and harder to comprehend.

Table 2
*Pre and Post-Test Class Averages, (N = 12)*

<table>
<thead>
<tr>
<th>Ch. 7 Pre-Test</th>
<th>Ch. 7 Post-Test</th>
<th>Ch. 8 Pre-Test</th>
<th>Ch. 8 Post-Test</th>
<th>Ch. 12 Pre-Test</th>
<th>Ch. 12 Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>46.00%</td>
<td>61.66%</td>
<td>29.83%</td>
<td>53.58%</td>
<td>37.75%</td>
<td>64.33%</td>
</tr>
</tbody>
</table>

*Figure 4. Pre and Post-Test Class Averages, (N = 12)*

The last difference was the class averages of the pre and post-test Ch.7, Ch.8, and Ch.12. Looking at Ch.7 (the non-treatment unit) and Ch.8 (non-treatment and treatment
sections), Ch.8 shows a greater percent increase from pre to post-test (Table 2). This showed that students were starting to learn on their own and improved with Bloom’s Taxonomy. Chapter 12 (treatment unit) showed the greatest percent increase from pre to post-test (Figure 4). Also, students’ scores started relatively high, but also ended with the highest percent class average. Students performed better on quizzes when students presented the demonstrations to the class and also had a firm understanding of the progressive levels of Bloom’s Taxonomy. Students worked with Bloom’s Taxonomy for three units and it was a reason why students did better on Ch.12 post-test.

Notes and Audience Question

Students took Cornell notes throughout the Ch.7, 8, and 12 demonstrations and over the respective chapters. Cornell notes seemed to be a way students were able to write down their thoughts and facts, while highlighting the main ideas of the chapters. The notes were graded with participation in mind. Students commented on taking the Cornell notes and most thought that they were helpful. “It was a way to organize the information and be able to look back and use it as a study guide,” said one student. Students took Cornell notes before the demonstrations and were able to add to their notes if they gained new information. This piece allowed students to look at different viewpoints and gave them the ability to record new findings.

Next, the student audience asked the presenter one question about the demonstration or the topic that was covered in the presentation. These questions were written on a note card and given to the presenter whom answered each question the following day. The results showed the student audience typically asked knowledge and
comprehension questions. Chapter 7 and the beginning of 8 showed that students asked more high-level thinking questions during the non-treatment (See Appendix Y). The treatment chapters (the last part of Ch.8 and all of Ch.12) showed a decrease in higher level thinking questions. During the treatment chapters, students knew how to ask higher level thinking questions and had background knowledge supporting their understanding of it, yet that total Analysis, Synthesis, and Evaluation questions that were asked was lower. Proof that students did understand how to ask higher level thinking questions was displayed on their post-tests; students understood the higher level thinking questions better than on their pre-test. Therefore, it can be accounted for as students did not fully participate in the question asking and did not take it serious.

**Muddiest Point**

The “Muddiest point” for Ch.7-12 showed that students mostly asked knowledge and comprehension questions. Students looked at this part of the project as a way to get quick answers to their questions. It showed that students primarily cared about getting the facts straight and did not care about being able to apply information, problem solve, or the ability to separate the parts from the whole; all which pertain to higher level thinking. The “Muddiest point” cards were mostly used for recognition and interpretation.

The presenting student did answer all “Muddiest point” questions; therefore, it solidified that the presenting student understood the topic and did better in the short term with content knowledge and long term retention rate. The student audience was able to write the answers to the “Muddiest point” questions in their notes and used them to study
for tests and quizzes. As a result, the presenting student’s average quiz grades were superior to all students in the audience. In the classroom, students and teachers must realize that if a student is assigned to present a concept, on average, that student will be motivated to learn on their own and be a responsible learner in order to present correct information to the class. This is helpful to the teacher and also enables the student to take control of their own learning and be able to build upon their own thinking (Athanassiou, 2003).

**Student Demonstration**

The student demonstrations went very well. All students incorporated the six levels of Bloom’s Taxonomy into their demonstrations and presented the correct information. Students worked very hard on their presentations and as a result did gain short term as well as long term knowledge. The gains in short and long term knowledge and retention rate can be seen by their performance on their pre vs. post-tests and also on their quizzes.

**Quiz**

A 6 multiple-choice question quiz was administered after the teacher and student demonstrations and had one of each of the levels of Bloom’s Taxonomy present (See Appendix D, E, O, P, Q, and R). The purpose of the quiz was to see what level of Bloom’s Taxonomy students comprehended. The teacher could tell how well the students understood the demonstration along with the content (See Appendix Z, Table 4 and Figure 6).
Table 3

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Quiz Averages, (N = 12)</th>
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<tbody>
<tr>
<td>Ch. 7.1</td>
<td>73.75%</td>
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<td>Ch. 7.4</td>
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<tr>
<td>Ch. 12.3</td>
<td>68.08%</td>
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Figure 5. Quiz Class Averages, (N = 12)

When comparing the non-treatment units (Ch. 7.1, 7.4, and 8.4) with the treatment units (Ch. 8.5, 12.1, 12.2, and 12.3), the average quiz scores predominantly increased as the students progressed through the units. It showed that all students were quite skilled in Ch. 7.1, otherwise, Ch. 12 showed the most improvement. The average quiz grade on the non-treatment units was 60.69%, while the average quiz grade for the treatment units was 65.72%. On average, students performed better on the quizzes that included Bloom’s Taxonomy (in which students were aware of its presence) and student-led demonstrations (Figure 5). This infers that students did improve on their quiz scores if they understood how to decipher the multiple-choice quiz questions using the levels of Bloom’s
Taxonomy and that students learned the information more thoroughly if a student was presenting a demonstration instead of the teacher.

Comparing the student audience quiz grades for Ch.12 with the student-demonstrator’s quiz grades showed great promise. The data was as follows: Average quiz grade for student presenters for Quiz 12.1 was a 67.00%, while the student audience’s average was a 60.10%. The average quiz grade for the students that presented in Ch. 12.2 was an 86.80%, while the student audience averaged 74%. Lastly, the students that presented their demonstration in Ch. 12.3 had an average quiz grade of a 76.60% and the student audience had a 62.00%. In all cases the student-demonstrator performed better on their respective quiz showing that sub-question number three did have a positive affect on the student-demonstrator. Teachers should be aware that students perform better if they assign a student to present information on a certain topic and then take a quiz over it. That student, on average, is being a responsible learner and taking control of their own education. They understand the main ideas and many details about the topic; which lends itself to an effective presentation. Students also learn the material better when they have to teach it; as a result, it engages them in higher level thinking.

Table 4
Percent of Incorrect Responses on Quizzes using Bloom’s Taxonomy, (N = 12)

<table>
<thead>
<tr>
<th>Bloom’s Taxonomy Level/Question</th>
<th>Non-Treatment Ch. 7.1 – Ch. 8.4</th>
<th>Treatment Ch. 8.5 – Ch. 12.3</th>
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<tr>
<td>1-Knowledge</td>
<td>30.56%</td>
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<tr>
<td>2-Comprehension</td>
<td>30.56%</td>
<td>18.75%</td>
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<tr>
<td>3-Application</td>
<td>25.00%</td>
<td>52.08%</td>
</tr>
<tr>
<td>4-Analysis</td>
<td>58.33%</td>
<td>35.42%</td>
</tr>
<tr>
<td>5-Synthesis</td>
<td>50.00%</td>
<td>45.83%</td>
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</table>
The percent of incorrect responses on quizzes was measured using the non-treatment sections, Ch. 7.1, 7.4, and 8.4, and the treatment sections, Ch. 8.5, 12.1, 12.2, and 12.3, in correspondence with Bloom’s Taxonomy (See Appendix Z). Knowledge questions seemed to stay the same throughout the units, but the Bloom’s Taxonomy Comprehension questions showed a decrease in the percent incorrect. This means that students did better with comprehension in the treatment units due to the fact that students understood Bloom’s Taxonomy and students led the class demonstrations. The third level of Bloom’s Taxonomy is Application, and it showed that students did not do better on the quiz questions. Application is one of the hardest levels to teach, and students typically struggle with it. Also, the methodologies used in this AR project could make it difficult to assess whether students really are increasing in the Application levels of
Bloom’s Taxonomy. In the upper level Bloom’s Taxonomy questions, students did better overall. This suggests that students were aware of the type of multiple-choice question being asked. They related it to Bloom’s Taxonomy and thus showed superior ratings in these levels.

**Student Survey**

Student surveys did help out in terms of understanding what level students performed at, how they liked or disliked learning about Bloom’s Taxonomy, and if they learned from the demonstrations given in class. Chapter 7, 8, and 12 all showed signs of students wanting demonstrations to be incorporated within each unit and wanting to use their knowledge of Bloom’s Taxonomy to decipher what kind of multiple-choice question was being asked on tests and quizzes. One student said: “If I knew what kind of question they were asking, I could then make a more educated decision on what answer to choose.” In the following paragraph there are examples from each unit and from each question on the Student Survey (See Appendix J).

Question #1 asked if there was a key component that helped your understanding of the chapter, and students from Ch.7 thought that lectures, notes, and the “Muddiest point” really helped. Students from Ch.8 thought the same and also that the demonstrations and other activities within the chapter helped them learn the material. In Chapter 12, students thought that giving the demonstrations and doing “my project” really helped with comprehending the material. Question #2 asked if they felt they mastered anything in this particular chapter. It showed that students felt like they mastered at least one item in the chapter. Question #3 asked what made it difficult for
you to learn. The answers confirmed that students really needed lecture, the
demonstrations from the students, and they needed an understanding of the kind of
question that was being asked on the multiple-choice test in order to effectively learn an
idea. Students were asked to declare one thing they learned about their own learning
style and Question #4 proved that students started to understand how they learned
individually. They started to become aware of what they needed in order to learn and
acquire both short-term content knowledge and a long term retention rate of the material.
As students started to understand Bloom’s Taxonomy and see more and more
demonstrations, they began to see that explaining material to others helps them, that they
needed diagrams and visual aids to learn, and that if they understood the type of question
being asked it was easier to find the correct answer on a multiple-choice test. Question
#5 asked about study skills. Students wanted to change the way they memorized in
chapter 7, and in chapter 8 they wanted to be more efficient in studying; while in chapter
12 students wanted to be present in class, read the textbook more, and learn to understand
the overall picture. Question #6 asked about the teacher-led demonstrations vs. the
student-led demonstrations. In Ch.7 students thought the demonstrations did help, yet
they were a little confused and did not take them serious when the teacher presented.
Chapter 8 showed that most students (9 out of 12) thought the demonstrations helped, and
in Ch. 12 students said yes, the demonstrations helped and they remembered the activity
that was presented and certain concepts. Question #7 allowed students to voice their
opinion on Bloom’s Taxonomy. In Ch. 7 students did not know what it was, while in Ch.
8 students thought the concept map we did in class helped them relate Bloom’s
Taxonomy and the concepts in their mind. They also thought they were better able to focus in on the kind of question that was posed and categorize the type of question that was asked on the multiple-choice test. In Ch. 12, the demonstrations which were in the synthesis category assisted them in learning the concepts. Question #8 asked if students felt confident about their answers on the post-test and if these questions were on a Biology 101 test in college could they answer it correctly. Most students thought they could in all Chapters. Question #9 gave evidence for students agreeing with the fact that they benefitted in their understanding of biology by going through Chapters 7, 8, and 12. Question #10 asked about the pre-test and if that aided them in the post-test. All students agreed or strongly agreed except for one student in chapter 12, that person disagreed. One student asked if they could use the pre-test to study for the post-test. I did not give an answer to the question that was written on the student survey, and that student did not ask again. Question #11 pertained to the Muddiest Point and if it aided them in the post-test. All students agreed that it did help. Finally, question #12 asked if the demonstrations did help on the post-test. Students all agreed or strongly agreed in all chapters.

Overall students agreed that the demonstrations did help their understanding of the material. Students remembered the demonstrations from their peers better than when the teacher demonstrated a concept. Students remembered the demonstrations and used that knowledge on the test. Everyone agreed that Bloom’s Taxonomy helped them when deciphering what type of question was being asked in a multiple-choice test or quiz. If they knew the type of question being asked then they could interpret the question better
and come up with an educated answer to the question. Administering a Student Survey allowed me, the teacher, to recognize how students learn and what tools they needed in order to learn.

**Teacher Journal**

The teacher journal allowed me, the teacher, to write down my interpretations of the students and how the AR project was going. My thoughts about teacher-led demonstrations vs. student-led demonstrations changed throughout the process. In the following paragraphs I explain the progress of thoughts using the nine questions that prompted me to give answers in my teacher journal (See Appendix K).

I found I answered questions about the AR impacting the student audience only when the treatment was applied during Ch. 12, the student-led demonstrations. Yet, when I answered about the impact the demonstrations had on the student audience, I felt that it had a positive affect. I felt the student audience paid more attention and got more out of the demonstrations. Students were able to remember certain concepts because their fellow classmate presented the topic. I wrote, “Some presentations were up-beat and funny! The audience laughed.” I also believed that students started to better understand the levels of Bloom’s Taxonomy. The student audience was able to see how other people applied Bloom’s Taxonomy to learning and the demonstrations. During the Ch. 12.2 student presentations I wrote in my Teacher Journal, “The presentation was given using Prezi. Students paid attention and were engaged. Bloom’s Taxonomy was highlighted in each slide.” I also wrote, “Students asked the student-presenter questions.” After reading the student surveys, I knew that it was a positive experience for the student audience as
well. One student survey said “I remembered the activity which helped me remember certain concepts.”

The impact on the student demonstrator was also a positive experience. I sensed that students knew the information better when they presented it to the class. Students were engaged in their own learning and were active learners. In my teacher journal I wrote, “Students felt proud of themselves for answering the student audience questions.” Students became self sufficient. This was my goal, and I know that students felt the same way because of their answers in the student surveys. One student wrote: “Giving presentations helped me understand this chapter.” Another wrote: “Doing my project.” Every student \((N = 12)\) wrote something similar. The key component that helped their understanding of the chapter had something to do with them presenting a demonstration to the class.

The student-led demonstrations had an impact on me, the teacher. I was actively assisting students with collecting information and looking over their shoulder to make sure they were presenting the correct information to the class. This was a tremendous amount of work, yet very rewarding. I knew that students were more responsible and actively engaged in their own learning. In my journal I wrote, “I was impressed with how they used Bloom’s Taxonomy in their presentations/demos.”

There was an impact on the long term retention rate when students presented the demonstrations versus when the teacher presented the demonstrations. The student audience was actively engaged in learning and listening to the student presenter compared to when I, the teacher, presented a demonstration. In my teacher journal for
the teacher demonstration Ch. 7.4 I wrote: “Students did not ask questions; it was a quiet class.” As a result I noted that the quiz grades for Ch.7.4 were quite low; the average was 54.25%. I felt that students did pay more attention to their fellow classmates when they presented. Next, students that presented had to learn the material in more detail, thus retained the information better; the average quiz grades for the presenting student versus the student audience was higher. Finally, students thought that they could remember the information better when their classmates were presenting, and it showed when comparing students’ quiz grades for the non-treatment and treatment units. Students scored higher in the treatment unit with the higher levels of Bloom’s Taxonomy.

I observed change happen when students started to present their demonstrations and they truly had to learn the levels of Bloom’s Taxonomy. During the student demonstrations, students showed how their topic related to the last three levels of Bloom’s Taxonomy; thus, they were much more connected and their understanding of topics ran deeper. Students were active in their own learning and became self-sufficient learners. The presenting students were very creative with their demonstrations. One student had the class play the age old game of “Simon Says.” This represented the way the cell goes through checkpoints as it develops.

The idea of student-led demonstrations vs. teacher-led demonstrations with progressive levels of Bloom’s Taxonomy can be a benefit and a detriment to my teaching. First, it was a benefit because students were finally able to understand the levels of Bloom’s Taxonomy and were actively engaged in their own learning. Students understood the content knowledge in the short term and remembered the information and
could apply it, thus this technique created a higher retention rate in the long term. Last, this could be a detriment to my teaching in only a small way. A situation where the student audience was given incorrect information from the student demonstrator could have caused some issues, and by proofing the information the students were going to present, I could alter their information if I found any discrepancies. But, I think this was a great way for students to take control of their own learning and still have the assistance of the teacher.

In the future I would do things similar; yet, I would incorporate more units into my study and number of participating students. This would give me more data to work with and be able to come to more precise conclusions. I would also like students to take the audience questions more seriously. I would stress the fact that the audience wants to make sure they are asking the presenter a higher level thinking question and not just a knowledge or comprehension question. This would enable the audience to work with higher level thinking questions more and also make the presenter think and evaluate their own responses to the questions.

**INTERPRETATION AND CONCLUSION**

In this investigation strategies were implemented with the purpose of improving student engagement and learning in the biology classroom. I investigated whether or not a student-led demonstration versus a teacher-led demonstration had an impact on the retention rate of AP biology students. A progressive Bloom’s Taxonomy technique was used in accordance with a student-led demonstration. I believed students reached higher
levels of Bloom’s Taxonomy and became self-sustained critical thinkers, which in turn supported their own higher level thinking.

The Primary question I asked in my Action Research was: What impact do student-led demonstrations versus teacher-led demonstrations have on the retention rate of AP biology students?

The sub-questions I wished to answer in my Action Research are:

1.) How will teacher-led demonstrations affect the retention rate of AP biology students?

2.) What impact do student-led demonstrations have on the student audience in terms of retention rate?

3.) What impact does the student demonstration have on the demonstrator themselves?

4.) What impact do the student-led demonstrations have on the teacher?

5.) How will using Bloom’s Taxonomy in student-led demonstrations and teacher-led demonstrations affect the long term retention rate of students?

Teacher-led demonstrations have affected the retention rate of AP biology students. Sub question number one taught me many things regarding my purpose with the overall research. First, according to the student surveys and my own teacher journal, students would rather listen to a student-presenter than a teacher-presenter. It was more exciting and students were more active in taking control of their own learning (I wrote, “Some presentations were up-beat and funny! The audience laughed.”). Second, students learned more and were able to reach higher levels of Bloom’s Taxonomy if the student
led the demonstration. The Methodologies in this research paper showed this to be true in all cases, thus the retention rate of students was higher when a student presented the demonstration (Ch. 12 Post-Test class average 64.33%, Ch. 12.3 student presenter quiz average was 76.60% while student audience was 62.00%).

Sub question two, what impact do student-led demonstrations have on the student audience in terms of retention rate, gave real insight into how students learned and what affected their learning. The student audience asked questions of the presenter to increase their knowledge base, wrote down their “Muddiest point” and received an answer, and the most important was that the student audience remembered what the student-presenter demonstrated (Chapter 8 student surveys showed that most students (9 out of 12) thought the demonstrations helped, and in Ch. 12 students said yes that the demonstrations helped and that they remembered the activity that was presented and certain concepts). The audience had a connection with the student-demonstrator and as a result remembered the demonstration that was presented in greater detail than when the teacher presented the demonstration (non-treatment average quiz grade = 60.69%, treatment average quiz grade = 65.72%). The data analysis showed that on the post-test, students scored considerable higher than on the pre-test, and when compared to the post-tests of Ch. 7 and Ch. 8, Ch. 12 showed a p-value that was smaller (< 0.0001) and a difference in mean that started higher in all cases (pre-test = 37.75%, post-test = 64.33%, difference of 26.58%). Finally, students on average did better on their quizzes in the treatment unit, confirming that students learned more and would prefer student-demonstrators over teacher-
demonstrators (non-treatment unit average quiz grade = 60.69%, treatment unit = 65.72%).

There was a dramatic impact on the student-demonstrator themselves as they presented their demonstration. The student-demonstrator showed that they understood the information more completely than the student audience. Quiz grades were higher and showed they learned the content knowledge in more detail for the short term. In all cases the student-demonstrator performed better on their respective quiz showing that sub-question number 3 did have a positive affect on the student-demonstrator (Ch.12.1 = 67% vs. 60.1%, Ch. 12.2 = 86.8% vs. 74.00%, Ch. 12.3 = 76.60% vs. 62.00%). Next, the post-tests of Ch.12, the treatment, demonstrated more improvement than the non-treatment units and also had a higher average mean (post-test = 64.33%). Lastly, the student surveys showed students understood the information in more detail if they were the student-demonstrator.

The student-led demonstrations had an impact on me, the teacher. I actively assisted students in collecting information and looked over their shoulder to make sure they were presenting the correct information to the class (Two teacher journal entries expressed it was hard and I had to make sure students presented correct information). This was a lot of work, yet it was very rewarding. I knew that students were more responsible and actively engaged in their own learning. Students took control of their own education and seemed to be proud of what they had accomplished. As a teacher, these are the milestones you hope your students reach. I will continue to find different ways of
challenging my students with student-led demonstrations and different ways for them to present.

How will using Bloom’s Taxonomy in student-led demonstrations and teacher-led demonstrations affect the long term retention rate of students? Analyzing the data for pre and post-test Ch.7, 8, and 12 gave me some insight. During Ch.7 the non-treatment was enforced and the treatment was not yet implemented. Chapter 8, allowed for the non-treatment and also the treatment to be ran. Lastly, Chapter 12 included the treatment. Thus, I was able to compare what happened in terms of the pre and post-test for Ch.7, 8, and 12. I am 95% confident that the true mean of the differences in the interval for Ch. 7, 8, and 12 pre and post-test were above zero indicating this was an improvement in teaching design in the classroom in some way. The means on the pre and post-test started higher in both cases for Ch.12.

Next, the post-test showed that in the non-treatment unit (Ch.7), students did better on the lower level Bloom’s Taxonomy questions (68.25%), but in the non-treatment and treatment unit (Ch.8), students excelled in the upper level Bloom’s Taxonomy questions (65.48%). Furthermore, students followed the non-treatment unit pattern and did better on the lower level Bloom’s Taxonomy questions in the Ch. 12 treatment unit (68.56%). Overall, students did do extremely well on the Ch.12 post-test and got the highest average percentage rate of multiple-choice test questions correct. In terms of my teaching, I will continue to have students perform demonstrations, which in turn will help increase the retention rate of students. I will also continue to work hard to have students reach higher levels in Bloom’s Taxonomy. Teaching lends itself in
working with higher level learning, and if students continue to teach through demonstrations, they will soon reach the higher levels in Bloom’s Taxonomy all by themselves.

To finish, the quiz scores showed great promise using Blooms’ Taxonomy to further their understanding on a topic. On average, students increased in percent correct as they went from non-treatment to the treatment units. The Knowledge questions stayed the same as students went from non-treatment to treatment units, while the Comprehension increased showing students were able to grasp Comprehension questions. The third category, Application, showed that students decreased in their understanding from non-treatment to the treatment units; proving it is hard to acquire an understanding of Application type questions. Finally, the upper level Bloom’s Taxonomy (Analysis, Synthesis, and Evaluation) questions showed that students increased in their understanding of those types of questions. Students were better equipped and had a framework of Blooms’ Taxonomy to build upon when they reached Ch.12, the treatment unit. The statistics show that students were increasing their content knowledge and thus retention rate. Students were learning how to be better self-learners by using the Bloom’s Taxonomy technique and student-led demonstrations as their guides.

VALUE

As an instructor, the results have affected the way I teach. I will continue to give students pre-tests and compare them to post-tests to see if students’ retention rate has increased. Students do appreciate that I take the time to see if they are increasing in their
retention rate, their long term recognition of information. I will also take the time to assess student’s short term content knowledge increase using quizzes. If students know how they are performing and at what level, student confidence will increase and they take control of their learning. Using these techniques, students have figured out a little about their own learning style. Some students must work harder than others to recognize what level of Bloom’s Taxonomy is portrayed in a multiple choice question. As students start to recognize the different levels, they seem to realize the depth of the question and are able to answer it with more confidence. Lastly, students presenting demonstrations while using correct science techniques and a progressive Bloom’s Taxonomy technique throughout the presentation has given students a chance to take control of their own learning. It has proved that students become responsible learners and take control of how they learn, and it affects their retention rate of information. Students are capable of retaining information better if they present the demonstration, rather than a teacher-led demonstration. Students are active learners and engaged in their own education. I will expand my use of student-led demonstrations in the classroom in the future. I would like to incorporate several units throughout a semester where students present demonstrations and use progressive levels of Bloom’s Taxonomy in the presentation. I would also like to have groups of students present demonstrations, giving them the chance to be more creative and to learn from others in their group.

If I was to continue this research, I would like to ask the question of whether or not students need Bloom’s Taxonomy incorporated into the student-led demonstrations in order to increase retention rate. I would like to test more units and also keep track of the
statistics over many years to see if the data aligns within the same chapters. I would also like to see if Bloom’s Taxonomy gives students confidence to present their demonstration and allow for a higher retention rate because of it? I would like to continue using student surveys and ask more questions pertaining to student thoughts and feelings of confidence and how comfortable they feel when presenting a demonstration. I would like to ask if students believe that student-led demonstrations help them reach higher levels of Bloom’s Taxonomy and thus have a higher retention rate. Lastly, I would like to know if this would be a sustainable practice for a teacher over the course of their career.

The results of this AR project are of great value to me as a teacher. I believe that students did reach higher levels in thinking and became their own steward in being active in their own education by using a progressive Bloom’s Taxonomy technique in student-led demonstrations. Students retain information better if they teach the information to others. As a result, I will continue to have students’ present demonstrations to their classmates.
REFERENCES CITED


APPENDICES
APPENDIX A

AR METHODOLOGIES IMPLEMENTATION PLAN
### AR Methodologies Implementation Plan

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<tr>
<th>Day</th>
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<th>Demo</th>
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APPENDIX B

DATA COLLECTION METHODOLOGIES
Data Collection Methodologies

### Data Collection Matrix

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Pre-test</th>
<th>Notes (Cornell)</th>
<th>Audience Questions</th>
<th>Muddiest point</th>
<th>Presentation/Demo</th>
<th>Quiz</th>
<th>Student Survey</th>
<th>Teacher’s Journal</th>
<th>Post-test</th>
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### Key
1. Data will show student baseline retention. Data before the research design.
2. Will give quantitative data.
3. Will show comprehension of information.
4. Will show long term retention.
5. Data will show progress during the research design.
6. Data reflects the value of the research design. Data will give student opinions.
APPENDIX C

CH.7 PRE AND POST-TEST
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) The presence of cholesterol in the plasma membranes of some animals
   A) makes the membrane less flexible, allowing it to sustain greater pressure from within the cell.
   B) enables the membrane to stay fluid more easily when cell temperature drops.
   C) makes the animal more susceptible to circulatory disorders.
   D) enables the animal to remove hydrogen atoms from saturated phospholipids.
   E) enables the animal to add hydrogen atoms to unsaturated phospholipids.

2) According to the fluid mosaic model of cell membranes, which of the following is a true statement about membrane phospholipids?
   A) They are free to depart from the membrane and dissolve in the surrounding solution.
   B) They frequently flip-flop from one side of the membrane to the other.
   C) They have hydrophilic tails in the interior of the membrane.
   D) They can move laterally along the plane of the membrane.
   E) They occur in an uninterrupted bilayer, with membrane proteins restricted to the surface of the membrane.

3) Which of the following is one of the ways that the membranes of winter wheat are able to remain fluid when it is extremely cold?
   A) by decreasing the number of hydrophobic proteins in the membrane
   B) by using active transport
   C) by increasing the percentage of cholesterol molecules in the membrane
   D) by increasing the percentage of unsaturated phospholipids in the membrane
   E) by co-transport of glucose and hydrogen

4) In order for a protein to be an integral membrane protein it would have to be which of the following?
   A) hydrophobic
   B) completely covered with phospholipids
   C) exposed on only one surface of the membrane
   D) hydrophilic
   E) amphipathic

5) When a membrane is freeze-fractured, the bilayer splits down the middle between the two layers of phospholipids. In an electron micrograph of a freeze-fractured membrane, the bumps seen on the fractured surface of the membrane are
   A) peripheral proteins.
   B) phospholipids.
   C) integral proteins.
   D) cholesterol molecules.
   E) carbohydrates.
6) Which of the following is a reasonable explanation for why unsaturated fatty acids help keep any membrane more fluid at lower temperatures?
A) Unsaturated fatty acids permit more water in the interior of the membrane.
B) The double bonds result in shorter fatty acid tails and thinner membranes.
C) Unsaturated fatty acids have a higher cholesterol content and therefore more cholesterol in membranes.
D) The double bonds block interaction among the hydrophilic head groups of the lipids.
E) The double bonds form kinks in the fatty acid tails, forcing adjacent lipids to be further apart.

7) Which of these are not embedded in the lipid bilayer at all?
A) integral proteins
B) transmembrane proteins
C) peripheral proteins
D) integrins
E) glycoproteins

8) What kinds of molecules pass through a cell membrane most easily?
A) small and hydrophobic
B) large and hydrophobic
C) monosaccharides such as glucose
D) ionic
E) large polar

9) Which of the following would likely move through the lipid bilayer of a plasma membrane most rapidly?
A) CO2
B) glucose
C) an amino acid
D) starch
E) K+

10) Which of the following statements is correct about diffusion?
A) It is very rapid over long distances.
B) It is an active process in which molecules move from a region of lower concentration to one of higher concentration.
C) It requires an expenditure of energy by the cell.
D) It requires integral proteins in the cell membrane.
E) It is a passive process in which molecules move from a region of higher concentration to a region of lower concentration.

11) Water passes quickly through cell membranes because
A) water movement is tied to ATP hydrolysis.
B) it is a small, polar, charged molecule.
C) it moves through aquaporins in the membrane.
D) the bilayer is hydrophilic.
E) it moves through hydrophobic channels.
The following information should be used to answer the following questions.

Cystic fibrosis is a genetic disease in humans in which chloride ion channels in cell membranes are missing or nonfunctional.

12) Chloride ion channels are membrane structures that include which of the following?
   A) sodium ions
   B) gap junctions
   C) hydrophilic proteins
   D) carbohydrates
   E) aquaporins

13) Which of the following would you expect to be a problem for someone with nonfunctional chloride channeling?
   A) buildup of excessive secretions in organs such as lungs
   B) inadequate secretion of mucus
   C) buildup of excessive secretions in glands such as the pancreas
   D) sweat that includes no NaCl
   E) mental retardation due to low salt levels in brain tissue

Use the diagram of the U-tube in Figure 7.2 to answer the questions that follow.

The solutions in the two arms of this U-tube are separated by a membrane that is permeable to water and glucose but not to sucrose. Side A is half filled with a solution of 2 M sucrose and 1 M glucose. Side B is half filled with 1 M sucrose and 2 M glucose. Initially, the liquid levels on both sides are equal.

![Figure 7.2](image)

14) Initially, in terms of tonicity, the solution in side A with respect to that in side B is
   A) hyperonic.
   B) plasmolyzed.
   C) isotonic.
   D) saturated.
   E) hypotonic.

15) After the system reaches equilibrium, what changes are observed?
   A) The water level is higher in side B then in side A.
   B) The molarity of sucrose and glucose are equal on both sides.
   C) The water level is unchanged.
   D) The water level is higher in side A than in side B.
   E) The molarity of glucose is higher in side A than in side B.
16) A patient has had a serious accident and lost a lot of blood. In an attempt to replenish body fluids, distilled water, equal to the volume of blood lost, is transferred directly into one of his veins. What will be the most probable result of this transfusion?

A) The patient's red blood cells will swell because the blood fluid is hypotonic compared to the cells.
B) The patient's red blood cells will shrivel up because the blood fluid is hypotonic compared to the cells.
C) It will have no unfavorable effect as long as the water is free of viruses and bacteria.
D) The patient's red blood cells will burst because the blood fluid is hypertonic compared to the cells.
E) The patient's red blood cells will shrivel up because the blood fluid is hypertonic compared to the cells.

17) Celery stalks that are immersed in fresh water for several hours become stiff and hard. Similar stalks left in a salt solution become limp and soft. From this we can deduce that the cells of the celery stalks are

A) hypotonic to fresh water but hypertonic to the salt solution.
B) hypotonic to both fresh water and the salt solution.
C) hypertonic to both fresh water and the salt solution.
D) hypertonic to fresh water but hypotonic to the salt solution.
E) isotonic with fresh water but hypotonic to the salt solution.

18) A cell whose cytoplasm has a concentration of 0.02 molar glucose is placed in a test tube of water containing 0.02 molar glucose. Assuming that glucose is not actively transported into the cell, which of the following terms describes the tonicity of the external solution relative to the cytoplasm of the cell?

A) flaccid
B) hypertonic
C) turgid
D) hypotonic
E) isotonic
Refer to Figure 7.3 to answer the following questions.

The solutions in the arms of a U-tube are separated at the bottom of the tube by a selectively permeable membrane. The membrane is permeable to sodium chloride but not to glucose. Side A is filled with a solution of 0.4 M glucose and 0.5 M sodium chloride (NaCl), and side B is filled with a solution containing 0.8 M glucose and 0.4 M sodium chloride. Initially, the volume in both arms is the same.

![Figure 7.3](image)

19) At the beginning of the experiment,
   A) side A is hypotonic to side B with respect to sodium chloride.
   B) side A is hypertonic to side B.
   C) side A is hypertonic to side B with respect to glucose.
   D) side A is hypotonic to side B.
   E) side A is isotonic to side B.

20) Which of the following statements correctly describes the normal tonicity conditions for typical plant and animal cells?
   A) The animal cell is in a hypertonic solution, and the plant cell is in a hypotonic solution.
   B) The animal cell is in a hypotonic solution, and the plant cell is in an isotonic solution.
   C) The animal cell is in a hypertonic solution, and the plant cell is in an isotonic solution.
   D) The animal cell is in an isotonic solution, and the plant cell is in a hypertonic solution.
   E) The animal cell is in an isotonic solution, and the plant cell is in a hypotonic solution.
SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

Read the following information and refer to Figure 7.4 to answer the following questions.

Five dialysis bags, constructed from a semi-permeable membrane that is impermeable to sucrose, were filled with various concentrations of sucrose and then placed in separate beakers containing an initial concentration of 0.6 M sucrose solution. At 10-minute intervals, the bags were massed (weighed) and the percent change in mass of each bag was graphed.

![Figure 7.4](image)

21) Which line represents the bag with the highest initial concentration of sucrose?  

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

22) Which line or lines represent(s) bags that contain a solution that is hypertonic at the end of 60 minutes?  
A) A and B  
B) B  
C) C  
D) D  
E) D and E

23) You are working on a team that is designing a new drug. In order for this drug to work, it must enter the cytoplasm of specific target cells. Which of the following would be a factor that determines whether the molecule enters the cell?  
A) lack of charge on the drug molecule  
B) blood or tissue type of the patient  
C) similarity of the drug molecule to other molecules transported by the target cells  
D) lipid composition of the target cells' plasma membrane  
E) non-polarity of the drug molecule

24) What is the voltage across a membrane called?  
A) electrochemical gradient  
B) osmotic potential  
C) chemical gradient  
D) membrane potential  
E) water potential
25) The movement of potassium into an animal cell requires
A) a cotransport protein.
B) low cellular concentrations of sodium.
C) high cellular concentrations of potassium.
D) an energy source such as ATP or a proton gradient.
E) a gradient of protons across the plasma membrane.

26) Proton pumps are used in various ways by members of every kingdom of organisms. What does this most probably mean?
A) Proton pumps are necessary to all cell membranes.
B) Proton pumps are fundamental to all cell types.
C) Proton pumps must have evolved before any living organisms were present on the earth.
D) Cells with proton pumps were maintained in each kingdom by natural selection.
E) The high concentration of protons in the ancient atmosphere must have necessitated a pump mechanism.

27) Several seriously epidemic viral diseases of earlier centuries were then incurable because they resulted in severe dehydration due to vomiting and diarrhea. Today they are usually not fatal because we have developed which of the following?
A) antibiotics against the viruses in question
B) hydrating drinks that include high concentrations of salts and glucose
C) intravenous feeding techniques
D) medication to prevent blood loss
E) antiviral medications that are efficient and work well with all viruses

28) An organism with a cell wall would have the most difficulty doing which process?
A) diffusion
B) osmosis
C) facilitated diffusion
D) active transport
E) phagocytosis

29) The difference between pinocytosis and receptor-mediated endocytosis is that
A) pinocytosis is nonselective in the molecules it brings into the cell, whereas receptor-mediated endocytosis offers more selectivity.
B) pinocytosis brings only water into the cell, but receptor-mediated endocytosis brings in other molecules as well.
C) pinocytosis can concentrate substances from the extracellular fluid, but receptor-mediated endocytosis cannot.
D) pinocytosis requires cellular energy, but receptor-mediated endocytosis does not.
E) pinocytosis increases the surface area of the plasma membrane whereas receptor-mediated endocytosis decreases the plasma membrane surface area.

30) In receptor-mediated endocytosis, receptor molecules initially project to the outside of the cell.
Where do they end up after endocytosis?
A) on the outside of vesicles
B) on the ER
C) on the inside surface of the vesicle
D) on the outer surface of the nucleus
E) on the inside surface of the cell membrane
APPENDIX D

CH.7.1 QUIZ
Ch. 7.1 Quiz

Name______________________________

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Which of the following is one of the ways that the membranes of winter wheat are able to remain fluid when it is extremely cold?
A) by increasing the percentage of cholesterol molecules in the membrane
B) by decreasing the number of hydrophobic proteins in the membrane
C) by co-transport of glucose and hydrogen
D) by using active transport
E) by increasing the percentage of unsaturated phospholipids in the membrane

2) According to the fluid mosaic model of cell membranes, which of the following is a true statement about membrane phospholipids?
A) They can move laterally along the plane of the membrane.
B) They frequently flip-flop from one side of the membrane to the other.
C) They have hydrophilic tails in the interior of the membrane.
D) They are free to depart from the membrane and dissolve in the surrounding solution.
E) They occur in an uninterrupted bilayer, with membrane proteins restricted to the surface of the membrane.

3) In order for a protein to be an integral membrane protein it would have to be which of the following?
A) hydrophilic
B) exposed on only one surface of the membrane
C) completely covered with phospholipids
D) hydrophobic
E) amphipathic

4) After a membrane freezes and then thaws, it often becomes leaky to solutes. The most reasonable explanation for this is that
A) the solubility of most solutes in the cytoplasm decreases on freezing.
B) the lipid bilayer loses its fluidity when it freezes.
C) the integrity of the lipid bilayer is broken when the membrane freezes.
D) transport proteins become nonfunctional during freezing.
E) aquaporins can no longer function after freezing.

5) When a membrane is freeze-fractured, the bilayer splits down the middle between the two layers of phospholipids. In an electron micrograph of a freeze-fractured membrane, the bumps seen on the fractured surface of the membrane are
A) integral proteins.
B) peripheral proteins.
C) cholesterol molecules.

6) Which of the following is true of the evolution of cell membranes?
A) The evolution of cell membranes is driven by the evolution of glycoproteins and glycopolipids.
B) Cell membranes have stopped evolving now that they are fluid mosaics.
C) An individual organism selects its preferred type of cell membrane for particular functions.
D) Cell membranes cannot evolve if proteins do not.
E) As populations of organisms evolve, different properties of their cell membranes are selected for or against.
APPENDIX E

CH. 7.4 QUIZ
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) What are the membrane structures that function in active transport?
   A) cytoskeleton filaments
   B) peripheral proteins
   C) cholesterol
   D) integral proteins
   E) carbohydrates

2) In most cells, there are electrochemical gradients of many ions across the plasma membrane even though there are usually only one or two electrogenic pumps present in the membrane. The gradients of the other ions are most likely accounted for by
   A) ion channels.
   B) carrier proteins.
   C) cotransport proteins.
   D) B and C only
   E) A, B, and C

3) Which of the following membrane activities require energy from ATP hydrolysis?
   A) movement of glucose molecules
   B) movement of water into a cell
   C) Na+ ions moving out of the cell
   D) facilitated diffusion
   E) movement of water into a paramecium

4) Glucose diffuses slowly through artificial phospholipid bilayers. The cells lining the small intestine, however, rapidly move large quantities of glucose from the glucose-rich food into their glucose-poor cytoplasm. Using this information, which transport mechanism is most probably functioning in the intestinal cells?
   A) facilitated diffusion
   B) active transport pumps
   C) simple diffusion
   D) phagocytosis
   E) exocytosis

5) Several seriously epidemic viral diseases of earlier centuries were then incurable because they resulted in severe dehydration due to vomiting and diarrhea. Today they are usually not fatal because we have developed which of the following?
   A) hydrating drinks that include high concentrations of salts and glucose
   B) antibiotics against the viruses in question
   C) medication to prevent blood loss
   D) intravenous feeding techniques
   E) antiviral medications that are efficient and work well with all viruses

6) Proton pumps are used in various ways by members of every kingdom of organisms. What does this most probably mean?
   A) Proton pumps must have evolved before any living organisms were present on the earth.
   B) The high concentration of protons in the ancient atmosphere must have necessitated a pump mechanism.
   C) Cells with proton pumps were maintained in each kingdom by natural selection.
   D) Proton pumps are fundamental to all cell types.
   E) Proton pumps are necessary to all cell membranes.
APPENDIX F

APPLYING BLOOM’S TAXONOMY
KNOWLEDGE

- remembering;
- memorizing;
- recognizing;
- recalling identification and recall of information
  - Who, what, when, where, how ...?
  - Describe

<table>
<thead>
<tr>
<th>Useful Verbs</th>
<th>Sample Question Stems</th>
<th>Potential activities and products</th>
</tr>
</thead>
<tbody>
<tr>
<td>tell</td>
<td>What happened after...? Make a list of the main events..</td>
<td></td>
</tr>
<tr>
<td>list</td>
<td>How many...?           Make a timeline of events.</td>
<td></td>
</tr>
<tr>
<td>describe</td>
<td>Who was it that...?    Make a facts chart.</td>
<td></td>
</tr>
<tr>
<td>relate</td>
<td>Can you name the...?   Write a list of any pieces of information you can remember.</td>
<td></td>
</tr>
<tr>
<td>locate</td>
<td>Describe what happened at...? List all the .... in the story.</td>
<td></td>
</tr>
<tr>
<td>write</td>
<td>Who spoke to...?       Make a chart showing...</td>
<td></td>
</tr>
<tr>
<td>find</td>
<td>Can you tell why...?   Make an acrostic.</td>
<td></td>
</tr>
<tr>
<td>state</td>
<td>Find the meaning of...? Recite a poem.</td>
<td></td>
</tr>
<tr>
<td>name</td>
<td>What is...?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Which is true or false...?</td>
<td></td>
</tr>
</tbody>
</table>

COMPREHENSION

- interpreting;
- translating from one medium to another;
- describing in one’s own words;
- organization and selection of facts and ideas
  - Retell...

<table>
<thead>
<tr>
<th>Useful Verbs</th>
<th>Sample Question Stems</th>
<th>Potential activities and products</th>
</tr>
</thead>
<tbody>
<tr>
<td>explain</td>
<td>Can you write in your own words...? Cut out or draw pictures to show a particular event.</td>
<td></td>
</tr>
<tr>
<td>interpret</td>
<td>Can you write a brief outline...? Illustrate what you think the main idea was.</td>
<td></td>
</tr>
<tr>
<td>outline</td>
<td>What do you think could of happened next...? Make a cartoon strip showing the sequence of events.</td>
<td></td>
</tr>
<tr>
<td>discuss</td>
<td>Who do you think...?    Write and perform a play based on the story.</td>
<td></td>
</tr>
<tr>
<td>distinguish</td>
<td>What was the main idea...? Retell the story in your words.</td>
<td></td>
</tr>
<tr>
<td>predict</td>
<td>Who was the key character...? Paint a picture of some aspect you like.</td>
<td></td>
</tr>
<tr>
<td>restate</td>
<td>Can you distinguish between...? Write a summary report of an event.</td>
<td></td>
</tr>
<tr>
<td>compare</td>
<td></td>
<td>Prepare a flow chart to illustrate the sequence of events.</td>
</tr>
<tr>
<td>describe</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPLICATION

- problem solving;
- applying information to produce some result;
- use of facts, rules and principles
  - How is...an example of...?
  - How is...related to...?
  - Why is...significant?

<table>
<thead>
<tr>
<th>Useful Verbs</th>
<th>Sample Question Stems</th>
<th>Potential activities and products</th>
</tr>
</thead>
<tbody>
<tr>
<td>solve</td>
<td>Do you know another instance where...?</td>
<td>Construct a model to demonstrate how it will work.</td>
</tr>
<tr>
<td>show</td>
<td>Could this have happened in...?</td>
<td>Make a diorama to illustrate an important event.</td>
</tr>
<tr>
<td>use</td>
<td>Can you group by characteristics such as...?</td>
<td>Make a scrapbook about the areas of study.</td>
</tr>
<tr>
<td>illustrate</td>
<td>What factors would you change if...?</td>
<td>Make a paper-mache map to include relevant information about an event.</td>
</tr>
<tr>
<td>construct</td>
<td>Can you apply the method used to some experience of your own...?</td>
<td>Take a collection of photographs to demonstrate a particular point.</td>
</tr>
<tr>
<td>complete</td>
<td>What questions would you ask of...?</td>
<td>Make up a puzzle game suing the ideas from the study area.</td>
</tr>
<tr>
<td>examine</td>
<td>From the information given, can you develop a set of instructions about...?</td>
<td>Make a clay model of an item in the material.</td>
</tr>
<tr>
<td>classify</td>
<td>Would this information be useful if you had a ...?</td>
<td>Design a market strategy for your product using a known strategy as a model.</td>
</tr>
</tbody>
</table>

ANALYSIS

- subdividing something to show how it is put together;
- finding the underlying structure of a communication;
- identifying motives;
- separation of a whole into component parts
  - What are the parts or features of...?
  - Classify...according to...
  - Outline/diagram...
  - How does...compare/contrast with...?
  - What evidence can you list for...?

<table>
<thead>
<tr>
<th>Useful Verbs</th>
<th>Sample Question Stems</th>
<th>Potential activities and products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyse</td>
<td>Distinguish</td>
<td>Examine</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td>Which events could have happened...?</td>
<td>I ... happened, what might the ending have been?</td>
<td>How was this similar to...?</td>
</tr>
<tr>
<td>Design a questionnaire to gather information.</td>
<td>Write a commercial to sell a new product.</td>
<td>Conduct an investigation to produce information to support a view.</td>
</tr>
</tbody>
</table>

**SYNTHESIS**

- creating a unique, original product that may be in verbal form or may be a physical object;
- combination of ideas to form a new whole
  - What would you predict/infer from...?
  - What ideas can you add to...?
  - How would you create/design a new...?
  - What might happen if you combined...?
  - What solutions would you suggest for...?

<table>
<thead>
<tr>
<th>Useful Verbs</th>
<th>Sample Question Stems</th>
<th>Potential activities and products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create</td>
<td>Can you design a ... to ...?</td>
<td>Invent a machine to do a specific task.</td>
</tr>
<tr>
<td>Invent</td>
<td>Why not compose a song about...?</td>
<td>Design a building to house your study.</td>
</tr>
<tr>
<td>Compose</td>
<td>Can you see a possible solution to...?</td>
<td>Create a new product. Give it a name and plan a marketing campaign.</td>
</tr>
<tr>
<td>Predict</td>
<td>If you had access to all resources how would you deal with...?</td>
<td>Write about your feelings in relation to...</td>
</tr>
<tr>
<td>Plan</td>
<td>Why don’t you devise your own way to deal with...?</td>
<td>Write a TV show, play, puppet show, role play, song or pantomime about...?</td>
</tr>
<tr>
<td>Construct</td>
<td>What would happen if...?</td>
<td>Design a record, book, or magazine cover for...?</td>
</tr>
<tr>
<td>Design</td>
<td>How many ways can you...?</td>
<td>Make up a new language code and write material using it.</td>
</tr>
<tr>
<td>Imagine</td>
<td>Can you create new and unusual uses for...?</td>
<td>Sell an idea.</td>
</tr>
<tr>
<td>Propose</td>
<td>Can you write a new recipe for a tasty dish?</td>
<td>Devise a way to...</td>
</tr>
<tr>
<td>Devise</td>
<td>can you develop a proposal which would...</td>
<td>Compose a rhythm or put new words to a known melody.</td>
</tr>
<tr>
<td>Formulate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EVALUATION

- making value decisions about issues;
- resolving controversies or differences of opinion;
- development of opinions, judgements or decisions
  - Do you agree...?
  - What do you think about...?
  - What is the most important...?
  - Place the following in order of priority...
  - How would you decide about...?
  - What criteria would you use to assess...?

<table>
<thead>
<tr>
<th>Useful Verbs</th>
<th>Sample Question Stems</th>
<th>Potential activities and products</th>
</tr>
</thead>
<tbody>
<tr>
<td>judge</td>
<td>Is there a better solution to...</td>
<td>Prepare a list of criteria to judge a ...</td>
</tr>
<tr>
<td>select</td>
<td>Judge the value of...</td>
<td>show. Indicate priority and ratings.</td>
</tr>
<tr>
<td>choose</td>
<td>Can you defend your position about...?</td>
<td>Conduct a debate about an issue of special interest.</td>
</tr>
<tr>
<td>decide</td>
<td>Do you think ... is a good or a bad thing?</td>
<td>Make a booklet about 5 rules you see as important. Convince others.</td>
</tr>
<tr>
<td>justify</td>
<td>How would you have handled...?</td>
<td>Form a panel to discuss views, eg &quot;Learning at School.&quot;</td>
</tr>
<tr>
<td>debate</td>
<td>What changes to ... would you recommend?</td>
<td>Write a letter to ... advising on changes needed at...</td>
</tr>
<tr>
<td>verify</td>
<td>Do you believe?</td>
<td>Write a half yearly report.</td>
</tr>
<tr>
<td>argue</td>
<td>Are you a ... person?</td>
<td>Prepare a case to present your view about...</td>
</tr>
<tr>
<td>recommend</td>
<td>How would you feel if...?</td>
<td></td>
</tr>
<tr>
<td>assess</td>
<td>How effective are...?</td>
<td></td>
</tr>
<tr>
<td>discuss</td>
<td>What do you think about...?</td>
<td></td>
</tr>
<tr>
<td>rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>prioritise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>determine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX G

TOOTHPICKASE ACTIVITY
Toothpickase Activity
Adapted from "Investigating Enzyme Reaction Rates Using Toothpickase" by Peggy O’Neill Skinner
© 1998 Carolina Biological Supply Company

Background
This exercise concerns enzymes and enzymatic regulation. More specifically, this lesson considers how the structure of an enzyme is related to its function. Enzymes have at least one active site. The substrate binds to the enzyme at the active site, but the enzyme will only be able to bind to the substrate at the active site if both have a complementary three-dimensional structure. Once the substrate has been bound to the enzyme’s active site, the enzyme will then be able to effect a lowering of the activation energy thereby increasing the rate of the reaction.

The active site of an enzyme may be blocked. When the active site of an enzyme is blocked, the enzyme is unable to bind with the substrate. If the enzyme is unable to bind with the substrate, then the enzyme cannot catalyze the reaction. If the active site of an enzyme is blocked, then the enzyme is inhibited. If the enzyme is inhibited, then it will not be able to catalyze or accelerate the rate of the reaction. Inhibition may be transitory or long lasting.

Typically, inhibitor molecules are used to regulate enzymes in biochemical pathways such as Phosphofructokinase or PFK. Inhibition of an enzyme in a biochemical pathway will essentially shut down the pathway. Hence, it is crucial to understand enzymatic inhibition, as it is the primary method of biochemical pathway regulation.

The main way that enzymes are inhibited is through allosteric inhibition. Allosteric inhibition is when an inhibitor molecule binds somewhere other than the active site. This binding causes the entire enzyme to change shape, called a conformational change. A conformational change in the enzyme affects the structure of the active site. If the shape of the active site is altered, then it will likely not be able to bind the substrate.

Vocabulary
Enzyme – structure that holds the substrate in place so that it can lower the activation energy of the reaction and therefore speed up the reaction rate
Quaternary structure – level of protein structure consisting of multiple subunits or chains
Active site – where the substrate actually binds
Substrate – binds to the enzyme at the active site (like a reactant in a chemical reaction)
Product – the end result of a chemical reaction
V-max – maximum rate of reaction

Background to Lab
Enzymes are agents that change the rate of a reaction without being changed themselves. In this activity, your hands become the functional part of an enzyme that we will call toothpickase. You will be called toothpickase since you will be breaking toothpicks and every enzyme ends in “-ase”. Your substrate is the toothpick. When you find a toothpick, you react with it and break it into two pieces. Your goal is to break toothpicks quickly and efficiently (without damaging the toothpickase in the process).
Toothpickase Handout

B. Boswell (2009)

Procedures

**PART 1**

1. Groups of 3 people
   a. 1 person will be breaking toothpicks
   b. Another person will be keeping track of how many toothpicks are broken
   c. Last person will be keeping time and recording data

2. Select approximately 250 toothpicks and divide them into 6 equal sized piles
3. You will be breaking toothpicks by holding the toothpick between your index finger and
   thumb of each hand.
4. The class will start metabolizing toothpicks at the same time
5. There are NO breaks in timing
6. Since you will be breaking toothpicks, make sure that the toothpick piles are
   conveniently located as speed is the main measurement

7. **RULES**
   a. You can only BREAK ONE (1) toothpick at a time
   b. You must BREAK the toothpick CLEANLY – if there is any attachment, it does
      not count

8. RECORD the total number of toothpicks broken at
   i. 0 sec. 10 sec. 30 sec. 60 sec. 120 sec. 180 sec.

**PART 2**

1. Same Groups, but switch responsibilities
2. Same Rules as in Part 1
3. Select approximately 250 toothpicks and divide them into 6 equal sized piles

4. **NOW:** the student breaking toothpicks can ONLY USE index and middle fingers on
   each hand.

5. The class will start metabolizing toothpicks at the same time
6. RECORD the total number of toothpicks broken at the same time intervals as in the
   previous part

**PART 3**

1. Same Groups, but switch responsibilities again
2. Same Rules as in Part 1 & Part 2
3. Select approximately 150 toothpicks and divide them into 6 equal sized piles
4. Select approximately 100 **round** toothpicks and divide them into the existing 6 piles

4. **NOW:** there are 2 types of toothpicks in each pile: Round and flat toothpicks
   a. If the breaker selects a **ROUND** toothpick, it must **NOT** be broken
      & placed in a separate pile at the end of the table

5. The class will start metabolizing toothpicks at the same time
6. RECORD the total number of toothpicks broken at the same time intervals as in the
   previous parts - **DO NOT** RECORD THE NUMBER OF ROUND TOOTHPICKS

---

2 of 4
Data Collection Tables

Toothpick Metabolism Data

<table>
<thead>
<tr>
<th>Time (seconds)</th>
<th>Toothpicks Metabolized PART 1</th>
<th>Toothpicks Metabolized PART 2</th>
<th>Toothpicks Metabolized PART 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>180</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reaction Rates
For each of the following time intervals, calculate the rate of reaction of the toothpickase enzyme using the following formula for the slope of the line graphed above:

\[
\text{Reaction Rate Calculation} = \frac{M_2 - M_1}{T_2 - T_1}
\]

M = number of toothpicks metabolized by a given point in time

T = time

Reaction Rate Data

<table>
<thead>
<tr>
<th>Time Period (seconds)</th>
<th>Rate of Reaction PART 1</th>
<th>Rate of Reaction PART 2</th>
<th>Rate of Reaction PART 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 to 30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 to 60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 to 120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120 to 180</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
GRAPHING

1. Graph the Toothpick Metabolism data in PART 1
2. Graph the Toothpick Metabolism data in PART 2
3. Graph the Toothpick Metabolism data in PART 3

** There must be 3 separate graphs
** Don’t forget to appropriately label the axes & provide a title
** You may use a computer program to graph the data or construct the graph by hand

ASSESSMENT QUESTIONS

1. In the Toothpickase activity, identify the following:
   a. Substrate:
   b. Enzyme:
   c. Active Site:
   d. Product:

2. How many subunits does Toothpickase have?

3. What is the quaternary structure of Toothpickase?

4. Explain how the Toothpickase activity modeled competitive inhibition?

5. Explain how the Toothpickase activity modeled allosteric (non-competitive) inhibition?

6. Explain how structure is related to function in the Toothpickase activity

7. What is the V-max in each of the three parts?
APPENDIX H

MODELING: INDUCED FIT IN A MULTIENZYME COMPLEX
Modeling: Induced Fit in a Multienzyme Complex

Advanced Preparation:

Prepare Model. Enlarge the patterns and cut out in paper or foam sheets. The pair of model pieces which make the active site of each enzyme should be made of the same color. The pieces should fit together nicely.

Pieces needed:

- 2- enzyme 1 active site
- 2- enzyme 2 active site
- 2- enzyme 3 active site
- 4- substrate pieces

Activity:

1. Arrange the 4 substrate pieces on the floor as shown in this handout.
2. Divide students into three groups representing three different enzymes.
3. Beginning with the enzyme 1 group, arrange the students in a line. Give an enzyme active site piece to the students on either end. Emphasize to students they are representing groups of amino acids making up the enzyme and that the foam active site pieces are a small part of the enzyme.
4. Students must stay connected by touching shoulder to shoulder. Relate this to the covalent bonds holding the amino acids together.
5. The students on the ends, holding the active site pieces, need to match them with the substrate. All the students (in the enzyme) will need to move in order for the end students to reach the substrate. In this way the students are able to model the change in enzyme shape seen in induced fit. Remove the first piece (Substrate A), and repeat with enzyme 2 and enzyme 3.
APPENDIX I

CH. 12 DEMONSTRATION
Ch.12 The Cell Cycle Presentations

Objective: You will choose from the 12 topics below and develop a presentation. You must come up with a creative way of using a demonstration to help get the information across to your classmates. You will present the demonstration to the class and discuss its meaning along with presenting the rest of your topic in some fashion to the class. (This could include a power point, notes, lecture etc.) While presenting your topic, you must use all levels of Bloom’s Taxonomy in some way. You will need 2 additional sources, besides your Biology textbook, in a written Bibliography (APA format) to hand in along with your demonstration and presentation. Be prepared to answer all “Muddiest Points” from the class the next day. If you are an audience member, your responsibilities are to take notes, write down the best question you can possibly think of to ask the presenter, and to write down your “Muddiest Point.”

Total points = 60.

Please sign up for one of the following Main Ideas.

1.) The Key Roles of Cell Division and Cellular Organization of the Genetic Material
2.) Distribution of Chromosomes During Eukaryotic Cell Division
3.) The Mitotic Phase Alternates with Interphase in the Cell Cycle and Phases of the Cell Cycle
4.) The Mitotic Spindle: A Closer Look
5.) Cytokinesis: A Closer Look
6.) Binary Fission
7.) The Evolution of Mitosis
8.) Evidence for Cytoplasmic Signals
9.) The Cell Cycle Control System
10.) The Cell Cycle Clock: Cyclins and Cyclin-Dependent Kinases
11.) Stop and Go Signs: Internal and External Signals at the Checkpoints
12.) Loss of Cell Cycle Controls in Cancer Cells

Mrs. Conner will initial next to each item as you finish them. You must include the following in your project:

______Demonstration of topic using all levels of Bloom’s Taxonomy in some fashion (Mrs. Conner must sign off on this before you present to the class. This will have to be done the day before you present).

______Be able to present demonstration to class
______Be able to discuss your topic in some fashion with the class
______2 additional sources
______Written Bibliography in APA format of your 2 additional sources
Be prepared to:

- answer questions from the class after you have presented your demonstration
- answer “Muddiest Points” from class the day after your presentation
- take a quiz over your topic the day after the presentation

Time line:

- Monday, October 25 – Assignment given
- Tuesday, October 26 – about 20 min. to work on assignment in class.
- Wednesday, October 27, 1st period – Library – time to look for 2 additional sources!
- Thursday, October 28, Early Bird and 1st period– Class time to work on project. (Early Bird Period writing center if needed.)
- Friday, October 29 – Early Bird and 1st period– Class time to work on project. (Early Bird Period writing center if needed.)
- Monday, November 1 - Projects are due. Presentations.

This presentation will include the following rubric:

<table>
<thead>
<tr>
<th>Points</th>
<th>0</th>
<th>4</th>
<th>7</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demonstration</strong></td>
<td>Did not present a demonstration</td>
<td>Demonstration was present. Little information was present in the demonstration. Could not understand demonstration – hard to follow.</td>
<td>Demonstration was present. Information was somewhat accurate in demonstration. Was sufficient in presenting information.</td>
<td>Demonstration was present. Information was accurate in demonstration. Went above and beyond when presenting demonstration. Very informative.</td>
</tr>
<tr>
<td><strong>Bloom’s Taxonomy</strong></td>
<td>Did not cover any of the level’s of Bloom’s Taxonomy, nor did you point them out to the class during the demonstration.</td>
<td>Covered at least 2 levels of Bloom’s Taxonomy. Did point them out to the class during the demonstration.</td>
<td>Covered at least 4 levels of Bloom’s Taxonomy. Did point them out to the class during the demonstration.</td>
<td>Covered all 6 levels of Bloom’s Taxonomy. Did point them out to the class during the demonstration.</td>
</tr>
<tr>
<td><strong>Presentation To Class</strong></td>
<td>Did not present. Presented to class. Did not act professional during presentation. Was not able to get point across to class. Was unprepared for presentation.</td>
<td>Presented to class. Did not act professional during presentation. Was able to get point across to class. Somewhat unprepared for presentation.</td>
<td>Presented to class. Did not act professional during presentation. Was able to get point across to class. Somewhat unprepared for presentation.</td>
<td>Presented to class. Did not act professional during presentation. Was able to get point across to class. Somewhat unprepared for presentation.</td>
</tr>
<tr>
<td><strong>Key Concept Discussed/Correct Information</strong></td>
<td>Did not have a key concept that was covered. Did not present the concept</td>
<td>Key concept was discussed. Concept was not fully explained to class.</td>
<td>Key concept was discussed. Concept was not fully explained to class.</td>
<td>Key concept was discussed. Concept was fully explained to class. All</td>
</tr>
<tr>
<td></td>
<td>that was assigned in class. Did not have correct information.</td>
<td>Did not have a way to show/discuss topic sufficiently. Information insufficient and incorrect: Little to no information</td>
<td>Missed some key components on explanation. Information somewhat correct; little information.</td>
<td>information correct; sufficient information. Was prepared to answer questions on topic.</td>
</tr>
<tr>
<td>-----------------------</td>
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<td>Bibliography</td>
<td>Did not have a Bibliography. Sources incorrectly written in APA format.</td>
<td>Bibliography present. 1 source written in APA format, but not written correctly.</td>
<td>Bibliography present. 1 source correctly written in APA format.</td>
<td>Bibliography present. 2 sources correctly written in APA format.</td>
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<tr>
<td>Muddiest Point</td>
<td>Did not present answers on Muddiest Points the day after presentation.</td>
<td>Did answer at least 4 Muddiest Points. Insufficient or incorrect information.</td>
<td>Did answer all Muddiest Points. Insufficient or incorrect information.</td>
<td>Did answer all Muddiest Points. Sufficient and correct information.</td>
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APPENDIX J

STUDENT SURVEY
Student Survey

1.) Was there one key component that helped your understanding of the chapter? If so, what was it?
2.) Name one thing that you are confident that you mastered in the chapter.
3.) Name something we did in this chapter that made it difficult for you to learn.
4.) What is one thing you found out about your own learning style? Please explain.
5.) What is one thing you would like to change about your study skills?
6.) Did the demonstrations help you learn the material? Why or why not?
7.) How did Bloom’s Taxonomy help you in this chapter?
8.) If questions from this chapter were on a Biology 101 pre-test at the college of your choice, do you think you would be able to answer the questions correctly?
9.) Do you feel that what you learned in this chapter benefitted your understanding of Biology? Circle the answer that best fits.
   a. = strongly disagree
   b. = disagree
   c. = undecided
   d. = agree
   e. = strongly agree
10.) Do you feel that the pre-test has helped you prepare for the final chapter test? Circle the answer that best fits.
    a. = strongly disagree
    b. = disagree
    c. =undecided
    d. = agree
    e. = strongly agree
11.) Do you feel that the “Muddiest Point” helped you prepare for the final chapter test? Circle the answer that best fits.
    a. = strongly disagree
    b. =disagree
    c. =undecided
    d. = agree
    e. = strongly agree
12.) Do you feel that the demonstrations in class have helped prepare you for the final chapter test? Circle the answer that best fits.
    a. = strongly disagree
    b. =disagree
    c. =undecided
    d. = agree
    e. = strongly agree
APPENDIX K

TEACHER JOURNAL
AR Teacher Journal
The Primary question I wish to ask in my Action Research is: What impact do student-led demonstrations versus teacher-led demonstrations have on the retention rate of AP biology students?
The sub-questions I wish to answer in my Action Research are:
1.) What impact do student-led demonstrations have on the student audience in terms of retention rate?
2.) What impact does the student demonstration have on the demonstrator themselves?
3.) What impact do the student-led demonstrations have on the teacher?
4.) How will using Bloom’s Taxonomy in student-led demonstrations versus teacher led demonstrations affect the long term retention rate of students?
5.) How will teacher-led demonstrations affect the retention rate of AP biology students?

Questions
1.) What impact do student-led demonstrations have on the student audience?
2.) What impact does the treatment have on the student demonstrator?
3.) What impact do the student-led demonstrations have on the teacher?
4.) How will using Bloom’s Taxonomy in student-led demonstrations and teacher led demonstrations affect the long term retention rate of students?
5.) What impact did the teacher-demo have on the students?
6.) Identify criteria that I believe will show where change is happening?
7.) How can this be a benefit and a detriment to my teaching?
8.) Is this a benefit to student learning?
9.) Would I do things different in the future?
APPENDIX L

CH.8 PRE AND POST-TEST
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Which term most precisely describes the cellular process of breaking down large molecules into smaller ones?
   A) dehydration
   B) catalysis
   C) metabolism
   D) anabolism
   E) catabolism

2) Which of the following is (are) true for anabolic pathways?
   A) They release energy as they degrade polymers to monomers.
   B) They do not depend on enzymes.
   C) They consume energy to build up polymers from monomers.
   D) They are usually highly spontaneous chemical reactions.

3) Whenever energy is transformed, there is always an increase in the
   A) entropy of the system.
   B) free energy of the system.
   C) entropy of the universe.
   D) enthalpy of the universe.
   E) free energy of the universe.

4) For living organisms, which of the following is an important consequence of the first law of thermodynamics?
   A) The energy content of an organism is constant.
   B) The entropy of an organism decreases with time as the organism grows in complexity.
   C) The organism ultimately must obtain all of the necessary energy for life from its environment.
   D) Life does not obey the first law of thermodynamics.
   E) Organisms are unable to transform energy.

5) Living organisms increase in complexity as they grow, resulting in a decrease in the entropy of an organism. How does this relate to the second law of thermodynamics?
   A) Living organisms are able to transform energy into entropy.
   B) Living organisms do not obey the second law of thermodynamics, which states that entropy must increase with time.
   C) Living organisms do not follow the laws of thermodynamics.
   D) Life obeys the second law of thermodynamics because the decrease in entropy as the organism grows is balanced by an increase in the entropy of the universe.
   E) As a consequence of growing, organisms create more disorder in their environment than the decrease in entropy associated with their growth.
6) Which of the following types of reactions would decrease the entropy within a cell?
   A) catabolism
   B) digestion
   C) hydrolysis
   D) respiration
   E) dehydration reactions

7) Which of the following is an example of potential rather than kinetic energy?
   A) a food molecule made up of energy-rich macromolecules
   B) a boy mowing grass
   C) water rushing over Niagara Falls
   D) a firefly using light flashes to attract a mate
   E) an insect foraging for food

8) The mathematical expression for the change in free energy of a system is $\Delta G = \Delta H - T\Delta S$. Which of the following is (are) correct?
   A) $T$ is the temperature in degrees Celsius.
   B) $\Delta S$ is the change in entropy, a measure of randomness.
   C) $\Delta G$ is the change in energy.
   D) $\Delta H$ is the change in entropy, the energy available to do work.

9) What is the change in free energy of a system at chemical equilibrium?
   A) greatly decreasing
   B) slightly increasing
   C) no net change
   D) slightly decreasing
   E) greatly increasing

10) A chemical reaction that has a positive $\Delta G$ is correctly described as
    A) endergonic.
    B) endothermic.
    C) exothermic.
    D) enthalpic.
    E) spontaneous.

11) Which of the following shows the correct changes in thermodynamic properties for a chemical reaction in which amino acids are linked to form a protein?
    A) $-\Delta H, +\Delta S, +\Delta G$
    B) $+\Delta H, -\Delta S, +\Delta G$
    C) $+\Delta H, -\Delta S, -\Delta G$
    D) $-\Delta H, -\Delta S, +\Delta G$
    E) $+\Delta H, +\Delta S, +\Delta G$

12) Which of the following best describes enthalpy (H)?
    A) the system's entropy
    B) the total kinetic energy of a system
    C) the condition of a cell that is not able to react
    D) the cell's energy equilibrium
    E) the heat content of a chemical system
13) Why is ATP an important molecule in metabolism?
   A) Its hydrolysis provides an input of free energy for exergonic reactions.
   B) Its terminal phosphate group contains a strong covalent bond that when hydrolyzed releases free energy.
   C) Its terminal phosphate bond has higher energy than the other two.
   D) It provides energy coupling between exergonic and endergonic reactions.
   E) A, B, C, and D

14) What term is used to describe the transfer of free energy from catabolic pathways to anabolic pathways?
   A) feedback regulation
   B) cooperativity
   C) bioenergetics
   D) energy coupling
   E) entropy

15) When chemical, transport, or mechanical work is done by an organism, what happens to the heat generated?
   A) It is used to generate ADP from nucleotide precursors.
   B) It is transported to specific organs such as the brain.
   C) It is lost to the environment.
   D) It is used to store energy as more ATP.
   E) It is used to power yet more cellular work.

16) When ATP releases some energy, it also releases inorganic phosphate. What purpose does this serve (if any) in the cell?
   A) It can be added to other molecules in order to activate them.
   B) It can only be used to regenerate more ATP.
   C) It is released as an excretory waste.
   D) It can enter the nucleus to affect gene expression.
   E) It can be added to water and excreted as a liquid.

17) What must be the difference (if any) between the structure of ATP and the structure of the precursor of the A nucleotide in DNA and RNA?
   A) The number of phosphates is three instead of one.
   B) The number of phosphates is three instead of two.
   C) The nitrogen-containing base is different.
   D) There is no difference.
   E) The sugar molecule is different.

18) Which of the following statements is (are) true about enzyme-catalyzed reactions?
   A) The reaction is faster than the same reaction in the absence of the enzyme.
   B) The reaction always goes in the direction toward chemical equilibrium.
   C) The free energy change of the reaction is opposite from the reaction in the absence of the enzyme.
   D) A and B only
   E) A, B, and C
19) Sucrose is a disaccharide, composed of the monosaccharides glucose and fructose. The hydrolysis of sucrose by the enzyme sucrase results in
   A) production of water from the sugar as bonds are broken between the glucose monomers.
   B) breaking the bond between glucose and fructose and forming new bonds from the atoms of water.
   C) the release of water from sucrose as the bond between glucose and fructose is broken.
   D) bringing glucose and fructose together to form sucrose.
   E) utilization of water as a covalent bond is formed between glucose and fructose to form sucrose.

20) Reactants capable of interacting to form products in a chemical reaction must first overcome a thermodynamic barrier known as the reaction's
   A) activation energy.
   B) free-energy content.
   C) heat content.
   D) entropy.
   E) endothermic level.

21) A solution of starch at room temperature does not readily decompose to form a solution of simple sugars because
   A) starch hydrolysis is nonspontaneous.
   B) the starch solution has less free energy than the sugar solution.
   C) the hydrolysis of starch to sugar is endergonic.
   D) starch cannot be hydrolyzed in the presence of so much water.
   E) the activation energy barrier for this reaction cannot be surmounted.

22) The active site of an enzyme is the region that
   A) binds the products of the catalytic reaction.
   B) is involved in the catalytic reaction of the enzyme.
   C) is inhibited by the presence of a coenzyme or a cofactor.
   D) binds allosteric regulators of the enzyme.

23) According to the induced fit hypothesis of enzyme catalysis, which of the following is correct?
   A) Some enzymes change their structure when activators bind to the enzyme.
   B) The binding of the substrate depends on the shape of the active site.
   C) The binding of the substrate changes the shape of the enzyme's active site.
   D) The active site creates a microenvironment ideal for the reaction.
   E) A competitive inhibitor can outcompete the substrate for the active site.
Refer to Figure 8.1 to answer the following questions.

24) Which curve represents the behavior of an enzyme taken from a bacterium that lives in hot springs at temperatures of 70°C or higher?
   A) curve 1      B) curve 2      C) curve 3      D) curve 4      E) curve 5

25) Increasing the substrate concentration in an enzymatic reaction could overcome which of the following?
   A) allosteric inhibition
   B) insufficient cofactors
   C) competitive inhibition
   D) saturation of the enzyme activity
   E) denaturation of the enzyme

26) Which of the following is likely to lead to an increase in the concentration of ATP in a cell?
   A) an increase in a cell's catabolic activity
   B) an increased influx of cofactor molecules
   C) an increase in a cell's anabolic activity
   D) the cell's increased transport of materials to the environment
   E) an increased amino acid concentration
27) When you have a severe fever, what may be a grave consequence if this is not controlled?
   A) removal of amine groups from your proteins
   B) binding of enzymes to inappropriate substrates
   C) change in the folding of enzymes
   D) destruction of your enzymes' primary structure
   E) removal of the amino acids in active sites

28) Some enzymatic regulation is allosteric. In such cases, which of the following would usually be found?
   A) cooperativity
   B) feedback inhibition
   C) the need for cofactors
   D) an enzyme with more than one subunit
   E) both activating and inhibitory activity

29) Among enzymes, kinases catalyze phosphorylation, while phosphatases catalyze removal of phosphate(s). A cell's use of these enzymes can therefore function as an on-off switch for various processes. Which of the following is probably involved?
   A) a change in the optimal pH at which a reaction will occur
   B) a change in the optimal temperature at which a reaction will occur
   C) the change in a protein's charge leading to cleavage
   D) the excision of one or more peptides
   E) the change in a protein's charge leading to a conformational change

The next questions are based on the following information.

A series of enzymes catalyze the reaction X → Y → Z → A. Product A binds to the enzyme that converts X to Y at a position remote from its active site. This binding decreases the activity of the enzyme.

30) What is substance X?
   A) the product
   B) an allosteric inhibitor
   C) a coenzyme
   D) a substrate
   E) an intermediate
APPENDIX M

CH.12 PRE AND POST-TEST
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) The centromere is a region in which
   A) the nucleus is located prior to mitosis.
   B) metaphase chromosomes become aligned at the metaphase plate.
   C) chromosomes are grouped during telophase.
   D) chromatids remain attached to one another until anaphase.
   E) new spindle microtubules form at either end.

2) What is a chromatid?
   A) a special region that holds two centromeres together
   B) a replicate chromosome
   C) another name for the chromosomes found in genetics
   D) a chromosome found outside the nucleus
   E) a chromosome in G1 of the cell cycle

3) Starting with a fertilized egg (zygote), a series of five cell divisions would produce an early embryo with how many cells?
   A) 4  
   B) 16  
   C) 8  
   D) 64  
   E) 32

4) If there are 20 chromatids in a cell, how many centromeres are there?
   A) 30  
   B) 20  
   C) 80  
   D) 40  
   E) 10

5) How do the daughter cells at the end of mitosis and cytokinesis compare with their parent cell when it was in G1 of the cell cycle?
   A) The daughter cells have the same number of chromosomes and the same amount of DNA.
   B) The daughter cells have half the amount of cytoplasm and half the amount of DNA.
   C) The daughter cells have the same number of chromosomes and half the amount of DNA.
   D) The daughter cells have half the number of chromosomes and twice the amount of DNA.
   E) The daughter cells have half the number of chromosomes and half the amount of DNA.

6) Which term describes centrioles beginning to move apart in animal cells?
   A) metaphase  
   B) prometaphase  
   C) anaphase  
   D) telophase  
   E) prophase

7) Which is the longest of the mitotic stages?
   A) anaphase  
   B) prophase  
   C) metaphase  
   D) telophase  
   E) prometaphase
SHORT ANSWER. Write the word or phrase that best completes each statement or answers the question.

Use the following information to answer the questions below.

The lettered circle in Figure 12.1 shows a diploid nucleus with four chromosomes. There are two pairs of homologous chromosomes, one long and the other short. One haploid set is symbolized as black and the other haploid set is gray. The chromosomes in the unlettered circle have not yet replicated. Choose the correct chromosomal conditions for the following stages.

![Figure 12.1](image)

8) one daughter nucleus at telophase of mitosis

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

9) If cells in the process of dividing are subjected to colchicine, a drug that interferes with the functioning of the spindle apparatus, at which stage will mitosis be arrested?
   A) interphase
   B) anaphase
   C) prophase
   D) metaphase
   E) telophase

10) A cell containing 92 chromatids at metaphase of mitosis would, at its completion, produce two nuclei each containing how many chromosomes?
   A) 46
   B) 16
   C) 92
   D) 12
   E) 23
11) If the cell whose nuclear material is shown in Figure 12.2 continues toward completion of mitosis, which of the following events would occur next?  
   A) spindle fiber formation  
   B) synthesis of chromatids  
   C) nuclear envelope breakdown  
   D) formation of telophase nuclei  
   E) cell membrane synthesis  

Use the data in Table 12.1 to answer the following question.

The data were obtained from a study of the length of time spent in each phase of the cell cycle by cells of three eukaryotic organisms designated beta, delta, and gamma.

<table>
<thead>
<tr>
<th>Cell Type</th>
<th>G&lt;sub&gt;1&lt;/sub&gt;</th>
<th>S</th>
<th>G&lt;sub&gt;2&lt;/sub&gt;</th>
<th>M</th>
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</thead>
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<tr>
<td>Beta</td>
<td>18</td>
<td>24</td>
<td>12</td>
<td>16</td>
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<tr>
<td>Delta</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gamma</td>
<td>18</td>
<td>48</td>
<td>14</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 12.1: Minutes Spent in Cell Cycle Phases

12) Of the following, the best conclusion concerning the difference between the S phases for beta and gamma is that  
   A) beta and gamma contain the same amount of DNA.  
   B) beta is a plant cell and gamma is an animal cell.  
   C) beta contains more RNA than gamma.  
   D) gamma contains more DNA than beta.  
   E) gamma contains 48 times more DNA and RNA than beta.

13) Where do the microtubules of the spindle originate during mitosis in both plant and animal cells?  
   A) centromere  
   B) centrosome  
   C) kinetochore  
   D) chromatid  
   E) centriole

14) If a cell has 8 chromosomes at metaphase of mitosis, how many chromosomes will it have during anaphase?  
   A) 4  
   B) 8  
   C) 2  
   D) 16  
   E) 1
15) Regarding mitosis and cytokinesis, one difference between higher plants and animals is that in plants
   A) sister chromatids are identical, but they differ from one another in animals.
   B) the spindles contain microfibrils in addition to microtubules, whereas animal spindles do not
       contain microfibrils.
   C) a cell plate begins to form at telophase, whereas in animals a cleavage furrow is initiated at
       that stage.
   D) spindle poles contain centrioles, whereas spindle poles in animals do not.
   E) chromosomes become attached to the spindle at prophase, whereas in animals chromosomes
       do not become attached until anaphase.

16) Movement of the chromosomes during anaphase would be most affected by a drug that
   A) increases cyclin concentrations.
   B) reduces cyclin concentrations.
   C) prevents elongation of microtubules.
   D) prevents attachment of the microtubules to the kinetochore.
   E) prevents shortening of microtubules.

17) Why do chromosomes coil during mitosis?
   A) to allow the chromosomes to move without becoming entangled and breaking
   B) to allow the chromosomes to fit within the nuclear envelope
   C) to provide for the structure of the centromere
   D) to increase their potential energy
   E) to allow the sister chromatids to remain attached

18) Which of the following best describes how chromosomes move toward the poles of the spindle
   during mitosis?
   A) Motor proteins of the kinetochore move the chromosomes along the spindle microtubules.
   B) Non-kinetochore spindle fibers serve to push chromosomes in the direction of the poles.
   C) The chromosomes are "reeled in" by the contraction of spindle microtubules.
   D) both A and B
   E) A, B, and C

The following is relevant to answer the questions below.

Nucleotides can be radiolabeled before they are incorporated into newly forming DNA and can therefore be assayed to track incorporation. In a set of experiments, a student-faculty research team used labeled T nucleotides and introduced these into culture of dividing human cells at specific times.

19) If mammalian cells receive a go-ahead signal at the G1 checkpoint, they will
   A) show a drop in MPF concentration.
   B) move directly into telophase.
   C) exit the cycle and switch to a nondividing state.
   D) complete the cycle and divide.
   E) complete cytokinesis and form new cell walls.
20) Which is a general term for enzymes that activate or inactivate other proteins by phosphorylating them?
   A) MPF
   B) Protein kinase
   C) Cdk
   D) Cyclin
   E) PDGF

21) Which of the following is a protein synthesized at specific times during the cell cycle that associates with a kinase to form a catalytically active complex?
   A) Cdk
   B) PDGF
   C) Protein kinase
   D) Cyclin
   E) MPF

22) Which of the following triggers the cell's passage past the G<sub>2</sub> checkpoint into mitosis?
   A) Cdk
   B) Protein kinase
   C) Cyclin
   D) MPF
   E) PDGF

23) DNA is replicated at this time of the cell cycle:
   A) M
   B) G<sub>0</sub>
   C) G<sub>1</sub>
   D) S
   E) G<sub>2</sub>

24) The 'restriction point' occurs here:
   A) G<sub>2</sub>
   B) S
   C) G<sub>1</sub>
   D) M
   E) G<sub>0</sub>

25) Nerve and muscle cells are in this phase:
   A) S
   B) G<sub>1</sub>
   C) M
   D) G<sub>2</sub>
   E) G<sub>0</sub>

26) A mutation results in a cell that no longer produces a normal protein kinase for the M phase checkpoint. Which of the following would likely be the immediate result of this mutation?
   A) The cell would undergo normal mitosis, but fail to enter the next G<sub>1</sub> phase.
   B) The cell would never leave metaphase.
   C) The cell would never enter prophase.
   D) The cell would prematurely enter anaphase.
   E) The cell would never enter metaphase.

27) Which of the following is true concerning cancer cells?
   A) When they stop dividing, they do so at random points in the cell cycle.
   B) They are not subject to cell cycle controls.
   C) They do not exhibit density-dependent inhibition when growing in culture.
   D) E and C only
   E) A, B, and C
The following questions are based on Figure 12.3.

Figure 12.3

28) In the figure above, mitosis is represented by which number?
   A) I       B) II      C) III     D) IV     E) V

29) G₁ is represented by which number(s)?
   A) I and V  B) II and IV   C) III  D) IV  E) V

30) Besides the ability of some cancer cells to overproliferate, what else could logically result in a tumor?
   A) metastasis
   B) inability of chromosomes to meet at the metaphase plate
   C) lack of appropriate cell death
   D) inability to form spindles
   E) changes in the order of cell cycle stages
APPENDIX N

THE CORNELL NOTE TAKING SYSTEM
The Cornell Note-taking System

Cue Column

Notetaking Column

1. **Record**: During the lecture, use the notetaking column to record the lecture using telegraphic sentences.

2. **Questions**: As soon after class as possible, formulate questions based on the notes in the right-hand column. Writing questions helps to clarify meanings, reveal relationships, establish continuity, and strengthen memory. Also, the writing of questions sets up a perfect stage for exam-studying later.

3. **Recite**: Cover the notetaking column with a sheet of paper. Then, looking at the questions or cue-words in the question and cue column only, say aloud, in your own words, the answers to the questions, facts, or ideas indicated by the cue-words.

4. **Reflect**: Reflect on the material by asking yourself questions, for example: “What’s the significance of these facts? What principle are they based on? How can I apply them? How do they fit in with what I already know? What’s beyond them?

5. **Review**: Spend at least ten minutes every week reviewing all your previous notes. If you do, you’ll retain a great deal for current use, as well as, for the exam.

Summary

After class, use this space at the bottom of each page to summarize the notes on that page.

Adapted from *How to Study in College 7/e* by Walter Pauk, 2001 Houghton Mifflin Company
APPENDIX O

CH.8.4 QUIZ
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Which of the following statements is (are) true about enzyme-catalyzed reactions?
   A) The free energy change of the reaction is opposite from the reaction in the absence of the enzyme.
   B) The reaction is faster than the same reaction in the absence of the enzyme.
   C) The reaction always goes in the direction toward chemical equilibrium.
   D) A and B only
   E) A, B, and C

2) How can one increase the rate of a chemical reaction?
   A) Increase the entropy of the reactants.
   B) Increase the activation energy needed.
   C) Decrease the concentration of the reactants.
   D) Cool the reactants.
   E) Add a catalyst.

3) According to the induced fit hypothesis of enzyme catalysis, which of the following is correct?
   A) The binding of the substrate changes the shape of the enzyme's active site.
   B) The binding of the substrate depends on the shape of the active site.
   C) Some enzymes change their structure when activators bind to the enzyme.
   D) A competitive inhibitor can outcompete the substrate for the active site.
   E) The active site creates a microenvironment ideal for the reaction.

4) Sucrose is a disaccharide, composed of the monosaccharides glucose and fructose. The hydrolysis of sucrose by the enzyme sucrase results in
   A) bringing glucose and fructose together to form sucrose.
   B) the release of water from sucrose as the bond between glucose and fructose is broken.
   C) utilization of water as a covalent bond is formed between glucose and fructose to form sucrose.
   D) production of water from the sugar as bonds are broken between the glucose monomers.
   E) breaking the bond between glucose and fructose and forming new bonds from the atoms of water.

5) During a laboratory experiment, you discover that an enzyme-catalyzed reaction has a $\Delta G$ of $-20$ kcal/mol. If you double the amount of enzyme in the reaction, what will be the $\Delta G$ for the new reaction?
   A) 0 kcal/mol
   B) $-40$ kcal/mol
   C) $+20$ kcal/mol
   D) $+40$ kcal/mol
   E) $-20$ kcal/mol
6) In order to attach a particular amino acid to the tRNA molecule that will transport it, an enzyme, an aminoacyl-tRNA synthetase, is required, along with ATP. Initially, the enzyme has an active site for ATP and another for the amino acid, but it is not able to attach the tRNA. What must occur in order for the final attachment to occur?

A) The 3' end of the tRNA must have to be cleaved before it can have an attached amino acid.
B) The tRNA molecule must have to alter its shape in order to be able to fit into the active site with the other two molecules.
C) The binding of the first two molecules must cause a 3-dimensional change that opens another active site on the enzyme.
D) The hydrolysis of the ATP must be needed to allow the amino acid to bind to the synthetase.
E) The ATP must first have to attach to the tRNA.
APPENDIX P

CH. 8.5 QUIZ
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) The mechanism in which the end product of a metabolic pathway inhibits an earlier step in the pathway is known as
   A) reversible inhibition.
   B) feedback inhibition.
   C) metabolic inhibition.
   D) noncooperative inhibition.
   E) allosteric inhibition.

2) Besides turning enzymes on or off, what other means does a cell use to control enzymatic activity?
   A) exporting enzymes out of the cell
   B) cessation of all enzyme formation
   C) hydrophobic interactions
   D) connecting enzymes into large aggregates
   E) compartmentalization of enzymes into defined organelles

3) Which of the following is an example of cooperativity?
   A) the binding of an end product of a metabolic pathway to the first enzyme that acts in the pathway
   B) protein function at one site affected by binding at another of its active sites
   C) binding of an ATP molecule along with one of the substrate molecules in an active site
   D) a molecule binding at one unit of a tetramer allowing faster binding at each of the other three
   E) the effect of increasing temperature on the rate of an enzymatic reaction

Use Figure 8.3 to answer the following questions.

Figure 8.3

4) Which of the following is the most correct interpretation of the figure?
   A) Energy from catabolism can be used directly for performing cellular work.
   B) Pi acts as a shuttle molecule to move energy from ATP to ADP.
   C) ADP + Pi are a set of molecules that store energy for catabolism.
   D) ATP is a molecule that acts as an intermediary to store energy for cellular work.
   E) Inorganic phosphate is created from organic phosphate.
5) Among enzymes, kinases catalyze phosphorylation, while phosphatases catalyze removal of phosphate(s). A cell's use of these enzymes can therefore function as an on-off switch for various processes. Which of the following is probably involved?
   A) the change in a protein's charge leading to a conformational change
   B) the excision of one or more peptides
   C) the change in a protein's charge leading to cleavage
   D) a change in the optimal pH at which a reaction will occur
   E) a change in the optimal temperature at which a reaction will occur

6) An important group of peripheral membrane proteins are enzymes, such as the phospholipases that attack the head groups of phospholipids leading to the degradation of damaged membranes. What properties must these enzymes exhibit?
   A) resistance to degradation
   B) membrane spanning domains
   C) water solubility
   D) lipid solubility
   E) independence from cofactor interaction
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) What is a chromatid?
   A) another name for the chromosomes found in genetics
   B) a chromosome found outside the nucleus
   C) a special region that holds two centromeres together
   D) a replicate chromosome
   E) a chromosome in G₁ of the cell cycle

2) How do the daughter cells at the end of mitosis and cytokinesis compare with their parent cell when it was in G₁ of the cell cycle?
   A) The daughter cells have the same number of chromosomes and twice the amount of DNA.
   B) The daughter cells have half the number of chromosomes and half the amount of DNA.
   C) The daughter cells have half the amount of cytoplasm and half the amount of DNA.
   D) The daughter cells have the same number of chromosomes and half the amount of DNA.
   E) The daughter cells have the same number of chromosomes and the same amount of DNA.

3) If there are 20 chromatids in a cell, how many centromeres are there?
   A) 30
   B) 80
   C) 40
   D) 20
   E) 10

4) Starting with a fertilized egg (zygote), a series of five cell divisions would produce an early embryo with how many cells?
   A) 32
   B) 8
   C) 4
   D) 64
   E) 16

5) For a newly evolving protist, what would be the advantage of using eukaryote-like cell division rather than binary fission?
   A) Cell division would allow for the orderly and efficient segregation of multiple linear chromosomes.
   B) Cell division allows for lower rates of error per chromosome replication.
   C) Cell division would be faster than binary fission.
   D) Binary fission would not allow for the formation of new organisms.
   E) Binary fission would not allow the organism to have complex cells.

6) Vinblastine is a standard chemotherapeutic drug used to treat cancer. Because it interferes with the assembly of microtubules, its effectiveness must be related to
   A) suppression of cyclin production.
   B) myosin denaturation and inhibition of cleavage furrow formation.
   C) inhibition of regulatory protein phosphorylation.
   D) inhibition of DNA synthesis.
   E) disruption of mitotic spindle formation.

7) Which is the longest of the mitotic stages?
   A) metaphase
   B) telophase
   C) prometaphase
   D) prophase
   E) anaphase
8) Cytokinesis usually, but not always, follows mitosis. If a cell completed mitosis but not cytokinesis, the result would be a cell with
   A) two nuclei.
   B) two abnormally small nuclei.
   C) high concentrations of actin and myosin.
   D) a single large nucleus.
   E) two nuclei but with half the amount of DNA.

9) A cell containing 52 chromatids at metaphase of mitosis would, at its completion, produce two nuclei each containing how many chromosomes?
   A) 16   B) 52   C) 46   D) 12   E) 23

10) If there are 20 centromeres in a cell at anaphase, how many chromosomes are there in each daughter cell following cytokinesis?
    A) 80   B) 10   C) 20   D) 40   E) 30

11) Movement of the chromosomes during anaphase would be most affected by a drug that
    A) prevents shortening of microtubules.
    B) increases cyclin concentrations.
    C) prevents attachment of the microtubules to the kinetochore.
    D) reduces cyclin concentrations.
    E) prevents elongation of microtubules.

12) Why do chromosomes coil during mitosis?
    A) to allow the chromosomes to move without becoming entangled and breaking
    B) to allow the chromosomes to fit within the nuclear envelope
    C) to increase their potential energy
    D) to provide for the structure of the centromere
    E) to allow the sister chromatids to remain attached
APPENDIX R

CH. 12.3 QUIZ
MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) Nerve and muscle cells are in this phase:
   A) M    B) G₀    C) S    D) G₁    E) G₂

2) If mammalian cells receive a go–ahead signal at the G₁ checkpoint, they will
   A) move directly into telophase.
   B) exit the cycle and switch to a nondividing state.
   C) show a drop in MFF concentration.
   D) complete the cycle and divide.
   E) complete cytokinesis and form new cell walls.

The following questions are based on Figure 12.3.

3) In the figure above, mitosis is represented by which number?
   A) I    B) II    C) III    D) IV    E) V

4) G₁ is represented by which number(s)?
   A) I and V    B) II and IV    C) III    D) IV    E) V
5) Besides the ability of some cancer cells to overproliferate, what else could logically result in a tumor?
   A) metastasis
   B) inability of chromosomes to meet at the metaphase plate
   C) changes in the order of cell cycle stages
   D) inability to form spindles
   E) lack of appropriate cell death

6) Cells from an advanced malignant tumor most often have very abnormal chromosomes, and often an abnormal total number of chromosomes. Why might this occur?
   A) Cancer cells are no longer anchorage dependent.
   B) Chromosomally abnormal cells can still go through cell cycle checkpoints.
   C) Chromosomally abnormal cells still have normal metabolism.
   D) Transformation introduces new chromosomes into cells.
   E) Cancer cells are no longer density dependent.
APPENDIX S

CH. 7 PRE VS. POST-TEST COMPARING MEANS
### Ch.7 Pre vs. Post-Test Comparing Means

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<th>Test of Ch.7 Data</th>
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Using **unpooled variances**

Student's t: -2.603

DF: 20.8925

P-value: 0.0083
APPENDIX T

CH. 7 PRE VS. POST-TEST DIFFERENCE OF MEANS
### Ch. 7 Pre vs. Post-Test Difference of Means

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Estimate: **15.6667** +/- **12.5192**

Range: **3.14748** to **28.1858**
APPENDIX U

CH.8 PRE VS. POST-TEST COMPARING MEANS
## Ch.8 Pre vs. Post-Test Comparing Means

### Test of Ch.8 Data

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Second attribute (numeric or categorical): Ch8_PostTest

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Using **unpooled variances**

Student's t: \(-5.088\)

DF: \(16.1263\)

P-value: \(0.00011\)
APPENDIX V

CH.8 PRE VS. POST-TEST DIFFERENCE OF MEANS
**Ch.8 Pre vs. Post-Test Difference of Means**

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Second attribute (numeric or categorical): Ch7_Pretest_

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Confidence level: **95.0**
Using **unpooled variances**
Estimate: **15.6667 +/- 12.5192**
Range: **3.14748 to 28.1858**
APPENDIX W

CH. 12 PRE VS. POST-TEST COMPARING OF MEANS
Ch. 12 Pre vs. Post-Test Comparing of Means

Test of Ch.12 Data

First attribute (numeric): Ch12_PreTest
Second attribute (numeric or categorical): Ch12_PostTest

Ho: Population mean of Ch12_PreTest equals that of Ch12_PostTest
Ha: Population mean of Ch12_PreTest is not equal to that of Ch12_PostTest

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Using unpooled variances
Student's t:  -6.149
DF: 18.7535
P-value: < 0.0001
APPENDIX X

CH. 12 PRE VS. POST-TEST DIFFERENCE OF MEANS
Ch. 12 Pre vs. Post-Test Difference of Means

Estimate of Ch. 12 Data

First attribute (numeric): Ch12_PostTest
Second attribute (numeric or categorical): Ch12_PreTest

Interval estimate for the population mean of Ch12_PostTest minus that of Ch12_PreTest

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Confidence level: **95.0**
Using **unpooled variances**

Estimate: 26.5833 +/- 9.05631
Range: 17.527 to 35.6396
APPENDIX Y

AUDIENCE QUESTIONS USING BLOOM’S TAXONOMY DATA TABLE
**Audience Questions using Bloom’s Taxonomy Data Table, (N = 12)**

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APPENDIX Z

INCORRECT RESPONSE TOTALS ON QUIZ VS. BLOOM’S TAXONOMY
### Incorrect Response Totals on Quiz vs. Bloom’s Taxonomy, (N = 12)

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APPENDIX AA

CH. 7, 8, AND 12 DATA
Ch. 7, 8, and 12 Data (N = 12)

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