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The effect of teaching biology concepts with animations compared to static cartoons on content retention

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THE EFFECT OF TEACHING BIOLOGY CONCEPTS WITH ANIMATIONS COMPARED TO STATIC CARTOONS ON CONTENT RETENTION

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ABSTRACT

This study explores the effect of animations versus static cartoons on students' content retention in a high school biology classroom. Students were pre-tested prior to the introduction of content in three units of study: cellular transport, protein synthesis, and mitosis. After instruction on the topic via PowerPoint presentations, students were randomly assigned to either the test group or experimental group for each unit. The control group was removed from the room and given a series of static cartoons with captions to view. The experimental group viewed an animation on the topic, accompanied by teacher narration, which consisted of the captions from static cartoons read aloud. The two groups were post-tested together immediately following the treatment, and again approximately 21 days later.

Analyses were done to compare both raw score means and normalized learning gains of the experimental and control groups. No statistically significant differences due to animations were found in these comparisons, though student engagement and class discussion were increased by the use of animations based on teacher observations. A class survey revealed an overwhelming interest in continued use of the animations as an instructional technique.

INTRODUCTION

Implementing Animations to Promote Retention

As Louisiana high school students are faced with cumulative end-of-course (EOC) tests from the Louisiana Department of Education at the end of each academic year, educators are challenged to teach content in a format that ensures student retention of material. Students can no longer rely on teacher- or district-created semester exams to demonstrate mastery of the year's content. When questioned about the content of the Biology EOC exam last year, the majority of my freshman Biology and Biology Honors students stated they struggled with content from earlier in the year more so than those concepts taught closer to the end of the year when the EOC is administered.

Numerous studies have found that the use of narrated animations is an effective teaching strategy to increase conceptual understanding (Rotbain et al. 2008; Rogers 2007; McClean et al. 2005; Stith 2004; Tversky et al. 2002; McLaughlin 2001; Mayer & Anderson 1992). While these existing studies demonstrate the effectiveness of using animations in the classroom, few delve into the effect of animations on long-term retention of taught material. Research of previous studies yielded only one study in which the author compared short-term and long-term retention rate of cell biology content in third year undergraduate courses (O'Day 2007).

Biology Honors students from my 2010-2011 and 2011-2012 classes noted significant unease with the material of the Louisiana Comprehensive Curriculum units on cellular transport, protein synthesis and cell replication. Each of these units of study is taught in the first half of the curriculum. Quiz, unit test, and semester exam grades reflected that the majority of the students struggled with the concepts covered in these

units, and even those few who initially tested well struggled to retain that knowledge. Students who mastered the content on weekly quizzes and the unit tests at the end of instruction failed to answer questions on the same content correctly on tests given much later (midterm and final exams).

Iberville Math, Science and Arts Academy East, the school at which this study was conducted, has implemented a one-to-one technology incentive with which every student and faculty member is loaned a personal Apple MacBook that each is allowed to take home throughout the school year. The availability of this and additional technology such as classroom SMARTboards and LCD projectors, as well as the district policy to use said technology in daily lessons, strongly supports the method of implementing animations in the Biology classroom lectures.

Animations in Education

Animations are now a common learning tool in classrooms throughout the world. As the availability of computers and accompanying presentation programs such as Microsoft PowerPoint and Apple Keynote become more widespread, so too are techniques to incorporate this technology as an instructional advantage (Kim et al. 2007). Teachers are encouraged by administration and educational reformists to make lessons more engaging for modern students who are continuously exposed to a technology-rich world of smart-phones, video gaming systems, wireless internet, and more. The so-called "traditional" means of teaching such as lecture, worksheet, and textbook lessons are being supplemented with, and in some instances replaced by, virtual lectures, web-based learning, and project-based, student-created movies or computer presentations where students may assimilate and apply the information they have received. Newer textbooks

are web-based, with accompanying services such as instructional videos by instructors, laboratory demonstrations, simulations, and a vast array of instructional animations (Sanger et al. 2001).

Instructional animations are valued for their ability to display temporal changes, as well as depiction of changes in position and form (Stith 2004). The static cartoons of textbooks must contain symbols to depict change such as arrows that may appear cluttered and cause confusion. Also, there is less need for interpretation or inference with animations compared to a picture with arrows or other symbols (McClean et al. 2005). Animations are dynamic and engaging to the majority of learners as attention is better maintained by movement and colors, and animations are generally considered aesthetically pleasing. Learning styles are also served well through animations. Visual learners are exposed to transitional images, auditory learners may rely on the accompanying narrations, and even kinesthetic learners may benefit from a more complex, interactive animation that can be manipulated to explore the possible effects. The information is presented in a consistent manner, as all learners are presented with the same information in an identical format and reading comprehension is not an obstacle to learning.

Potential disadvantages of using animations to instruct do exist. The educator must be careful in the development of the animation, or selecting the most appropriate animation. Animations can be too quick or too complex; the brain cannot process information as quick as the animation is moving, or the animation may be too involved and too much information is presented to be processed in the timeframe of the animation (Falvo 2008; Tversky et al. 2002). A major disadvantage is simply the logistics of the

instructional technique. If the technology necessary to present the animations malfunctions or become unavailable for any reason, the lesson can be a complete waste of time.

Previous Studies

Bradley Stith of the University of Colorado Denver tested the effect of using animations in addition to lecture in his undergraduate Cell Biology class (Stith 2004). In a class of 58 students he presented a lesson on apoptosis using PowerPoint slides, four of which explained the path to apoptosis involving the mitochondrion using both notes and static illustrations. At the end of the lesson, 27 randomly selected students were asked to wait in the hall as the remaining 31 students viewed a 65-second animation illustrating the same path to apoptosis. The animation was viewed four times. The other students were brought back in and all 58 students were given a quiz of 11 questions. Students who viewed the animations scored significantly higher on quizzes (14%) than those students who did not view animations.

As the particular interest of this study was how the use of animations may or may not affect long-term retention of content, it would have been interesting and helpful had Stith retested the material several weeks after the initial quiz. Stith readily admits his study was of a smaller scale, "merely a beginning", and more rigorous study needs to be done over multiple semesters to determine the value of animation in the classroom. The results of his simple study do offer strong enough evidence to warrant the continued research of animation's value as a teaching tool. His experimental design also offered valuable insight on how to model this study.

Sanger et al. (2001) tested the effects of animations as a teaching strategy at the University of Northern Iowa in a second semester introductory biology course. The study included 149 (predominantly freshmen) biology majors who were divided into six separate lab sections. Laboratory sections were randomly selected to serve as either control or experimental groups. The students of the experimental lab sections were shown two narrated computer animations involving molecular behaviors associated with the processes of diffusion, while the control lab sections were not given access to the animations.

Both groups were given the Diffusion and Osmosis Diagnostic Test (Odom 1995; Odom & Barrow 1995). This diagnostic test consists of twelve two-tier questions; the first tier is content based, and the second tier asks for a reasoning of the answers from the first tier. The second tier allows for the instructor to identify major misconceptions of students related to cellular transport content. Sanger et al. (2001) observed that no students from the experimental group held the first major misconception compared to 8% of the control group.

While 19% of students who viewed the animation still experienced the second major misconception associated with diffusion, 36% of the control group held the same misconception. It was found that the animations used in the study needed some improvements to avoid further misconceptions, but overall students who were exposed to the animations performed better on the concept test, with fewer misconceptions, than those who did not view the animations.

Sanger's study was the only study found that both tests the use of animations, and also uses the same Diffusion and Osmosis Diagnostic Test by Odom and Barrow that was

used in this study. While the experimental design varies significantly from this study's due to time restraints and sample sizes, Sanger's results lend to the validity and reliability of Odom and Barrow's diagnostic test. This is another example of a study that validates the use of animations to teach concepts, but does not include any delayed testing of content. The value of animations as a retention technique is not explored in this study.

The only research found to date of the effect of animations on retention rate of material was that of O'Day (2007) of the University of Toronto at Mississauga in Ontario, Canada. O'Day utilized two separate junior courses, Advanced Cell Biology and Human Development, with a total of 180 students completing the study. Animations without narration on three topics (cholesterol uptake, apoptosis, and the influenza virus), and graphics on two (cholesterol uptake (with legend) and apoptosis (without legend)), were provided online. Divided into five tutorial groups, students were given access to view either the web-based graphics or animations. The links were shut down directly after a specified viewing time. Immediately afterwards, students completed a questionnaire.

Students were given identical questions three weeks later to determine their retention of the material. The results showed that students not only scored higher directly after viewing animations compared to graphics, but also retained more of the information 21 days later after viewing the animation without narration compared to graphics on the same content with or without a legend.

Rationale for this Study

The purpose of this study was to determine if the use of teacher-narrated animations, in conjunction with lecture, can significantly improve the conceptual

understanding and long-term retention of biology concepts of my Biology Honors students. This study differed from previous studies in that it was conducted in a high school science classroom setting compared to undergraduate and graduate courses. Also, all but one study found did not delve into content retention of material taught with animations; this study tested for content retention. Since animations are so commonly provided by textbook publishers as ancillary materials to the textbooks, it seems worthwhile to study the animations as a tool to help students comprehend and retain concepts.

MATERIALS AND METHODS

Definition of the Study Population

The research was conducted in one section of a Biology Honors class, which consisted of 18 students, at Iberville Math, Science & Arts Academy – East (MSA-E) in Saint Gabriel, Louisiana. Of the 18, 14 were females and three were males. Students ranged in age from 13 to 16 years old. The class was taught as a freshman level course, but did include three sophomores and one junior. These students were transfers from other schools in the state that teach Biology as a sophomore course. These students had taken Physical Science as a freshman course, and still needed to satisfy the Biology curriculum requirement upon transfer to MSA-E. Two students in the class regularly received accommodations and modifications of assignments and assessments due to Special Education classification. Examples of these accommodations include shortened quizzes and tests, assessments read aloud, instructions read aloud, repeated, and clarified. For the purpose of including them in the study population, their assessments as related to the research were not modified.

The school is a grades K-12 magnet program in its fifth year, servicing 272 students (as of 2012) from the rural communities of Sunshine, St. Gabriel, and Carville, Louisiana. As shown in Table 1, the ethnicity demographics of the study population closely resembled that of the school population. Of these students, 158 (58%) receive either free or reduced lunches, an indicator of poverty. This was comparable to the study population, of which 50% received free or reduced lunch. The school is classified as a Title I school, which is a school that receives federal funds from the U.S. Department of

Education to help bridge the gap between students in lower-income areas and students of more affluent areas.

Table 1. Demographics of School and Study Populations.

Ethnicity for Iberville MSA East in St. Gabriel, LA*		
	School Population	Study Population
Black	61.8%	72.2%
White	30.5%	22.2%
Hispanic	4.8%	5.6%
Asian	2.2%	0%
Native American	0.7%	0%

***** Ethnicity of the whole school population (272 students, grades K-12) was compared to that of the study population, which consisted of one section (18 students, grades 9-11) of Biology Honors. This step was done to get a better understanding of the students in the study group.

Development of Pre- and Post-Tests

To gauge student learning, three tests were utilized to serve as both pre-tests and post-tests of content specific to cellular transport, mitosis and protein synthesis (Appendices A, C, E). The first pre/post-test given consisted of twelve two-tier questions from an Osmosis and Cellular Diffusion concept inventory (Odom & Barrow 1995). The remaining two pre- and post-tests were designed exclusively using ExamView question banks. ExamView is the test-generating software which accompanies the class textbook, Biology (Miller & Levine 2010). Questions from this software's test banks are correlated with the state of Louisiana's biology curriculum Grade Level Expectations, or GLEs. These GLEs are the state academic standards of the class content that students should

master throughout the year. As such, the ExamView questions are deemed high quality, as well as age- and grade-appropriate (Figure 1). Each pre/post-test consisted of 12 multiple-choice questions.

3. Which type of RNA brings the information in the genetic code from the nucleus to other parts of the cell?
a. rRNA
b. tRNA
c. mRNA
d. RNA polymerase

4. Which molecules are involved in protein synthesis?
a. transfer RNA, introns and mutagens
b. messenger RNA, introns and ribosomal RNA
c. ribosomal RNA, transfer RNA and mutagens
d. messenger RNA, transfer RNA and ribosomal RNA

Figure 1. Questions from Pre-/Post-test on Protein Synthesis. (ExamView 2010) [Test questions for units two and three were from the test software which accompanied the class textbook *Biology* (Miller and Levine 2010). Questions were high-quality and age-appropriate. All questions used in units two and three tests were multiple choice as shown.]

Study Design/ Administering Pre- and Post-tests

All students and parents or guardians of these students returned signed consent forms indicating willingness to participate in the study. Parental consent forms, student assent forms, and study design were approved by Louisiana State University's Institutional Review Board before research commenced (Appendix G).

Pre-tests were given to all students before the specific content was introduced. To increase interest and effort from students, bonus points were given for each question answered correctly. Pre-tests were collected and graded, and scores were recorded in an Excel spreadsheet with student indicator numbers to ensure security of student identities.

The computer on which the data was stored was password protected to further ensure security. Because these questions would be used again later as a post-test, pre-tests were not redistributed to students, nor were correct answers reviewed.

In the class immediately following the day of the pre-test, content was introduced using teacher-designed PowerPoint presentations with static cartoons and bulleted information (Biology, Miller & Levine 2010). Because the high school classes are only 45 minutes in length, it was sometimes necessary to cover the material over a span of two class meetings. In these cases, material covered in the PowerPoint presentation on the first day was briefly reviewed before continuing on with the presentation on the second day. At the end of the slideshow, an animation was readied for viewing. Sources of the animations for each unit varied (Giannini 2012, Miller & Levine 2010, McKinley & O'Loughlin 2006). A random half of the class was excused to a neighboring classroom with handouts of a series of static cartoons of a biological process accompanied by captions (Appendices B, D, F).

The remaining students viewed an animation of the same biological process no more than three times as the teacher narrated with a script identical to that of the captions provided on the handouts to students in the static cartoon group. The students who did not view the animation were brought back in, and all students were immediately given the post-test (Table 2). Post-tests were collected and graded, and again scores were recorded in the Excel data collection. Students were also awarded bonus points for questions answered correctly on the post-tests. This procedure was repeated for each of the remaining units of study. Each time a different portion of the class was removed (i.e. left side of room, right side of room, front half) prior to the animation viewing.

In an effort to observe any effect on content retention, the same post-tests were given approximately three weeks later. Students were again rewarded with bonus points for questions answered correctly. Students were post-tested again on unit one content 21 days later, the second unit post-test was administered 28 days later, and the third unit was post-tested again 14 days later. The dates of the secondary post-tests for units two and three were affected by Thanksgiving and Christmas holidays, respectively. As such, the school calendar did not allow for testing exactly 21 days later for each of the three units.

Table 2. Timeline of the Study.

	UNIT 1	UNIT 2	UNIT 3
Pre-test	Sept 21	Oct 19	Dec 3
Post-test	Sept 27 (4 classes)	Oct 29 (3 classes)	Dec 7 (4 classes)
21-day Post-test	Oct 18 (21 days)	Nov 26 (28 days)	Dec 21 (14 days)

(Dates that study assessments were administered for each unit are included. For each unit of study, the effort was made to pre-test, post-test, and post-test again to gauge retention within a similar timeframe.)

Analyses of raw score means were used to determine if any significant differences existed between the pre- and post-test scores of the control and experimental groups. Each group was also tested for differences between learning gains from pre-test to initial post-test, and again for learning gains from pre-test to 21-day post-test. Normalized student gain, <g>, was calculated using the formula: <g> = [(student's individual gain) ÷ (student's maximum possible gain)] (Slater et al. 2010). An example from this study is that of a student who scored a 2 out of the possible 12 on the mitosis pre-test and a 6 on the post-test. This student had a learning gain of 0.40 [(4) ÷ (10) = 0.40]. This is a proportion of what the student could have learned according to the post-test. A student with a perfect score would have a learning gain of 1.0. The mean learning gain, $< \overline{g} >$, for

each group was calculated using the formula: $<\bar{g}>$ = [(sum of all students' normalized gains) ÷ (number of students)] (Slater et al. 2010).

Upon completion of the research units, data were analyzed using GraphPad InStat version 3.00 for Windows 95, GraphPad Software, San Diego California USA, www.graphpad.com. For each unit, a Kruskal-Wallis (nonparametric ANOVA analog), along with a Dunn's Multiple Comparisons test, was run to determine if any statistically significant differences existed between the means of control and experimental groups. A parametric test was not appropriate, due to the fact that data in each unit of the study violated the test of normal distribution as determined by the Kolmogorov-Smirnov test for normality. Learning gains were calculated for control and experimental groups using pre-tests and post-tests, as well as pre-tests and 21-day post-tests. A two-tailed Mann-Whitney test was conducted to determine any statistical significance. The Kruskal-Wallis, Dunn's multiple comparisons, and Mann-Whitney tests were run with a pre-determined α level of 0.05.

RESULTS

In this study, the value of animations as a retention technique was explored. The animations were used in contrast to a series of sequential static cartoons. This was done to compare the images routinely seen in classroom texts to the web-based animations provided by textbook publishers, as well as animations created by experienced instructors.

The study was done for three separate units of content. The units were chosen for two main reasons. The first reason was the complexity of material, gauged by student remarks and teacher experience. The second reason was that these topics were covered early in the school year, and students often forgot the material. I was trying to develop methods that enhance retention. The first unit of study was cellular transport, with emphasis on diffusion and osmosis. The second unit of study was protein synthesis, taught in the steps of DNA replication, transcription and translation. The third and final unit of study was on mitosis.

Web-based animations were chosen by the instructor. Several factors were considered including complexity of animation, length of animation, overall appearance of animation, and ability to pause animation for screen shots to create static cartoons. Students were pre-tested prior to introduction of content. They were randomly assigned to control (static cartoons) or experimental group (animation), exposed to the treatment, and post-tested. Pre- and post-tests were created for the second and third units of study; the first unit was pre-/post-tested with a college-level cellular transport concept inventory. Raw score means were analyzed with a Kruskal-Wallis nonparametric ANOVA analog and Dunn's multiple comparisons test. Learning gains were calculated

using the formula: <g> = [(student's individual gain) ÷ (student's maximum possible gain)] (Slater et. al. 2010). Gains were calculated for pre-tests to post-tests and for pre-tests to 21 day post-tests. Gains were then analyzed using a Mann-Whitney test.

Unit one raw score means of control and experimental groups are shown in Figure 2. Comparison of control and experimental pre-tests scores showed no significance ($p>0.05$), indicating a similar level of prior knowledge of the cellular transport content going into the study. The results of the initial post-test showed no significant difference ($p>0.05$) between the two groups. The same was true for the 21 day post-test results. While no statistical significance was determined, Figure 2 does seem suggestive. The experimental group started at a lower mean than the control group, but received higher scores on both the initial post-test and the 21-day post-test.

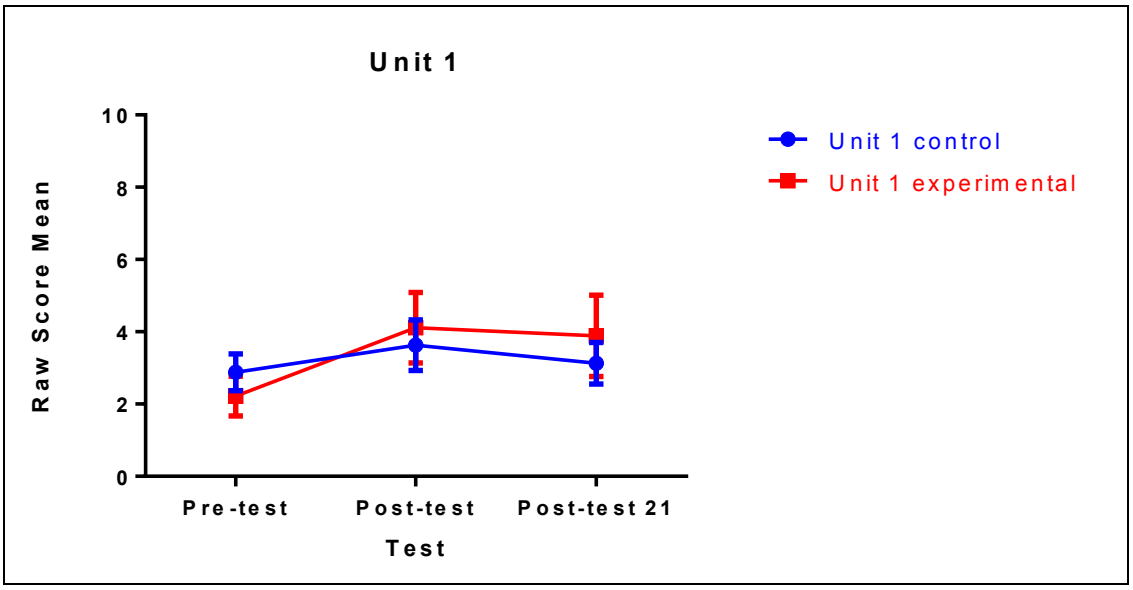

Figure 2. Unit 1: Cellular Transport Control vs. Experimental Raw Scores. [Each point represents the average correct score (out of 12 questions) on each of the assessments, with the standard error. The material tested in Unit 1 of the study was from Unit 1 of the biology Louisiana Comprehensive Curriculum, "The Cell", with an emphasis on diffusion and osmosis.]

Despite a lack of significant difference, the learning gains also seem to suggest that the animations worked as an instructional technique. As shown in Figure 3, the experimental group displayed a higher learning gain (NLG=0.211 $\pm$ 0.082) than the control group (NLG=0.077 $\pm$ 0.070) from the pre-test to the initial post-test. The experimental group again displayed a higher learning gain (NLG=0.197 $\pm$ 0.098) than the control group (NLG=0.020 $\pm$ 0.051) from the pre-test to the 21-day post-test (Figure 4). The experimental group not only demonstrated a higher level of learning, but seemed to retain more of the content for the 21-day post-test.

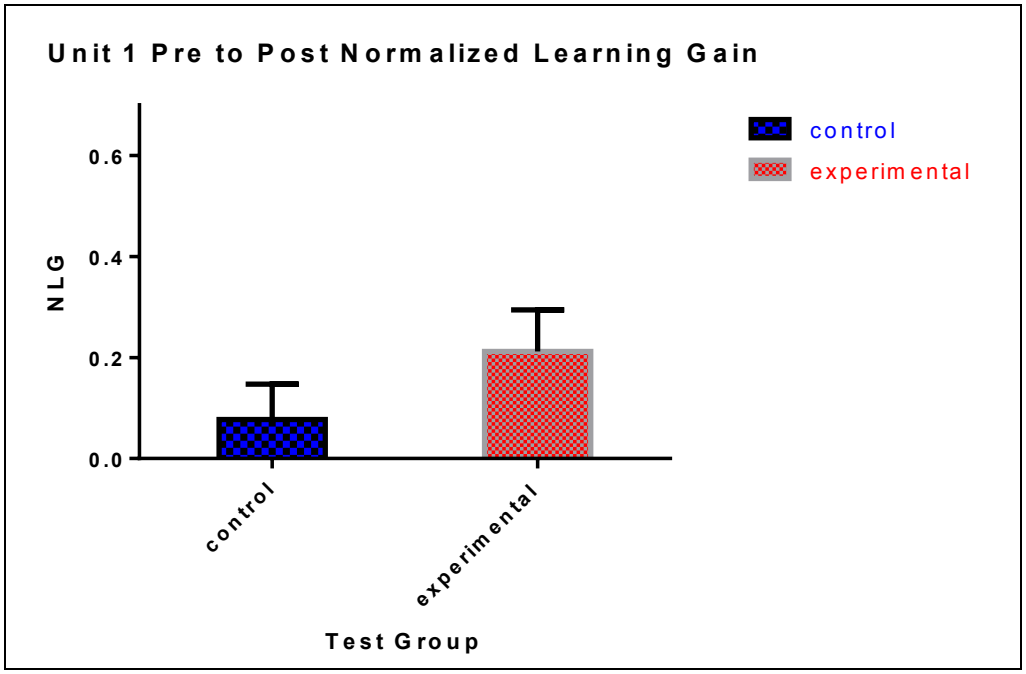

Figure 3. Unit 1: Normalized Learning Gains from Pre-test to Post-test.
[Learning gains were calculated with Slater et al.'s (2001) formula for each student, from pre-test to post-test. These were used to calculate a mean learning gain for each study group and then analyzed with a Mann-Whitney test. This learning gain is the proportion of the material that students learned from the pre-test to post-test as assessed by the post-test.]

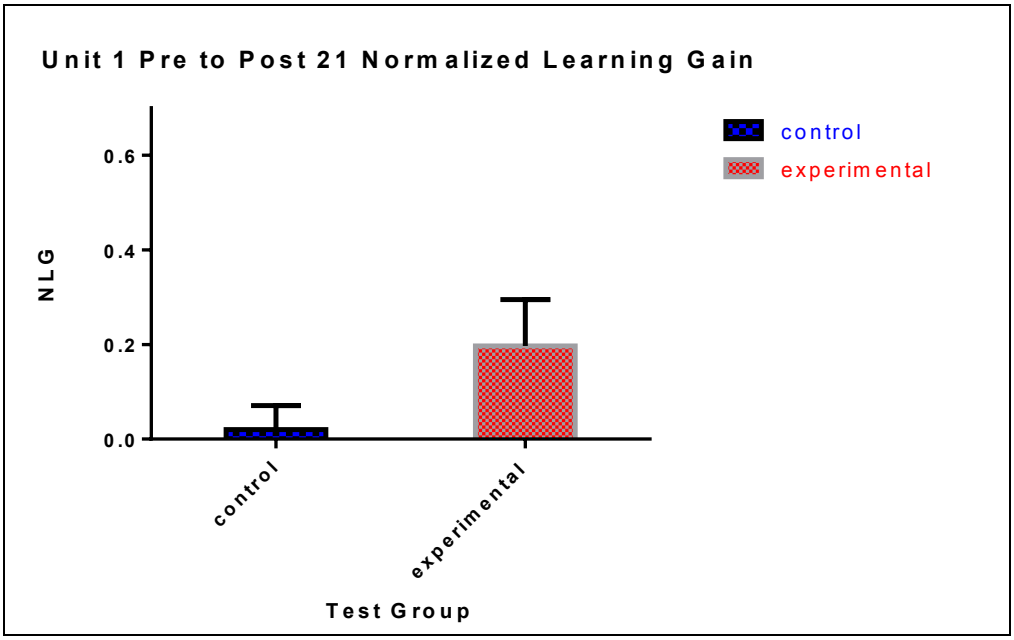

Figure 4. Unit 1: Normalized Learning Gains from Pre-test to 21-day Post-test. [Learning gains were calculated with Slater et al.'s (2001) formula for each student, from pre-test to 21-day post-test. These were used to calculate a mean learning gain for each study group, then analyzed with a Mann-Whitney test. This learning gain is the proportion of the material that students learned from the pre-test to 21-day post-test as assessed by the 21-day post-test. This is the amount of material that was considered "retained" by the student.]

Figure 5 shows unit two raw score means of control and experimental groups. Comparison of control and experimental pre-tests scores again showed no significant differences ($p>0.05$), indicating a similar level of prior knowledge of the protein synthesis content going into the study. The results of the initial post-test showed no significant difference ($p>0.05$) between the two groups. In fact, the groups had equal post-test mean raw scores. No significant differences ($p>0.05$) were found between the control and experimental groups' 21-day post-test scores. Figure 5 does show a trend of an increase in control group's mean raw score between post- and 21-day post-tests, while the experimental group's mean raw score decreased between the two post-tests. This

increase is significant, and was most likely caused by one or two more correct answers in the entire control group.

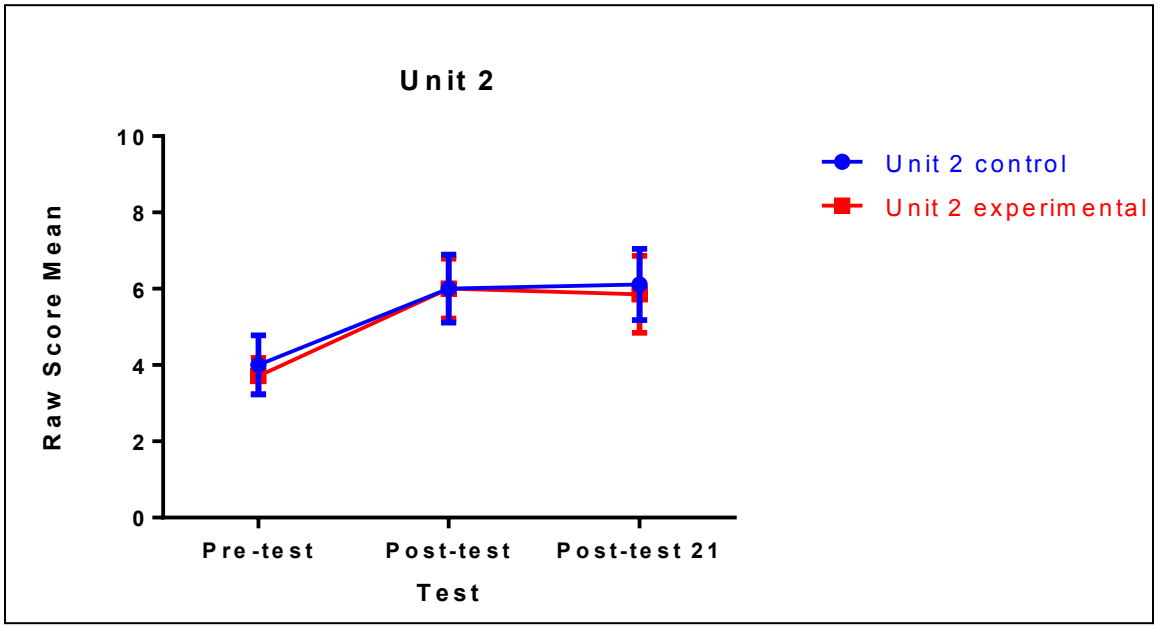

Figure 5. Unit 2: Protein Synthesis Control vs. Experimental Raw Scores. [Each point represents the average correct score (out of 12 questions) on each of the assessments, with the standard error. The material tested in Unit 2 of the study was from Unit 2 of the biology Louisiana Comprehensive Curriculum, "Reproduction and Genetics", and was explicitly related to protein synthesis.]

As shown in Figure 6, the experimental group displayed a slightly higher learning gain (NLG=0.255 $\pm$ 0.111) than the control group (NLG=0.013 $\pm$ 0.195) from the pre-test to the initial post-test. The experimental group again displayed a higher learning gain, though much smaller in difference (NLG=0.201 $\pm$ 0.179), than the control group (NLG=0.176 $\pm$ 0.180) from the pre-test to the 21-day post-test (Figure 7). No statistically significant differences were seen in comparison of the gains.

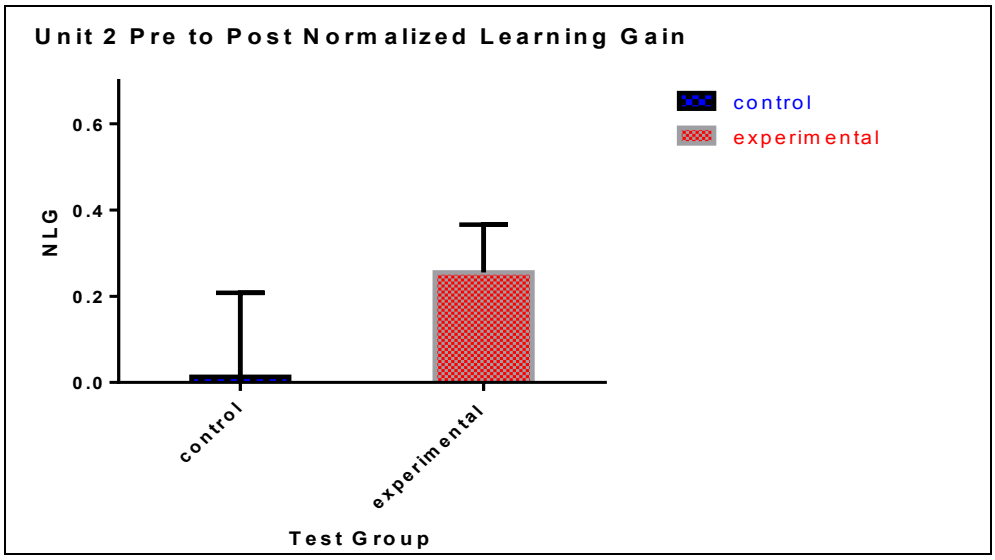

Figure 6. Unit 2: Normalized Learning Gains from Pre-test to Post-test.
[Learning gains were calculated with Slater et al.'s (2001) formula for each student, from pre-test to post-test. These were used to calculate a mean learning gain for each study group, then analyzed with a Mann-Whitney test. This learning gain is the proportion of the material that students learned from the pre-test to post-test as assessed by the post-test.]

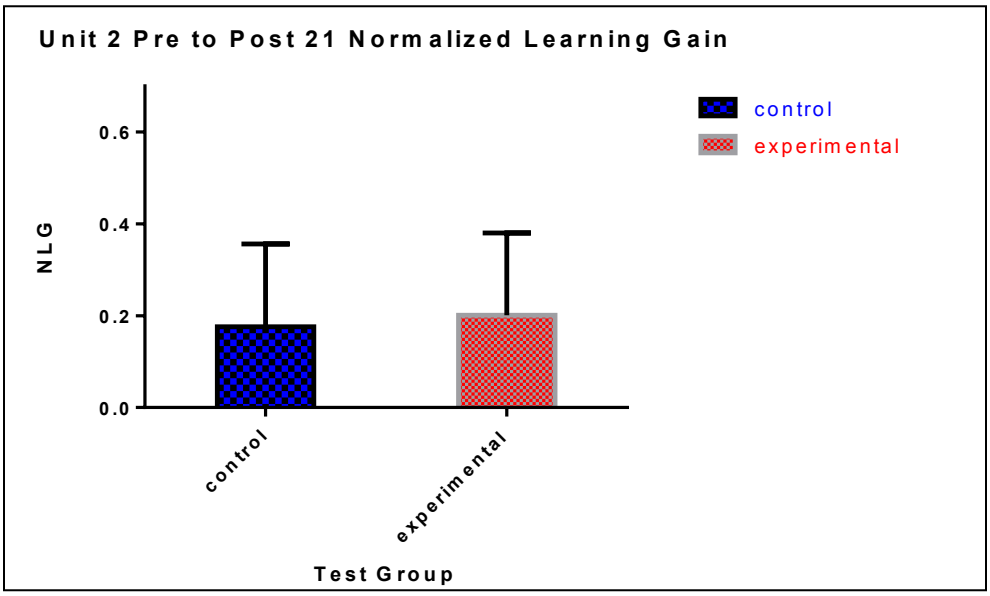

Figure 7. Unit 2: Normalized Learning Gains from Pre-test to 21-day Post-test.
[Learning gains were calculated with Slater et al.'s (2001) formula for each student, from pre-test to 21-day post-test. These were used to calculate a mean learning gain for each study group, then analyzed with a Mann-Whitney test. This learning gain is the proportion of the material that students learned from the pre-test to 21-day post-test as assessed by the 21-day post-test. This is the amount of material that was considered "retained" by the student.]

Unit three raw score means of control and experimental groups are shown in Figure 8. Once again, comparison of control and experimental pre-tests scores showed no differences ($p>0.05$), indicating a similar level of prior knowledge of the mitosis content going into the study. The results of the initial post-test showed no significant difference ($p>0.05$) between the two groups. As indicated by the graph, the control group was able to bridge the gap and almost met the experimental group's mean raw score. The experimental group produced a higher raw score mean for the 21-day post-test, showing a greater amount of retention.

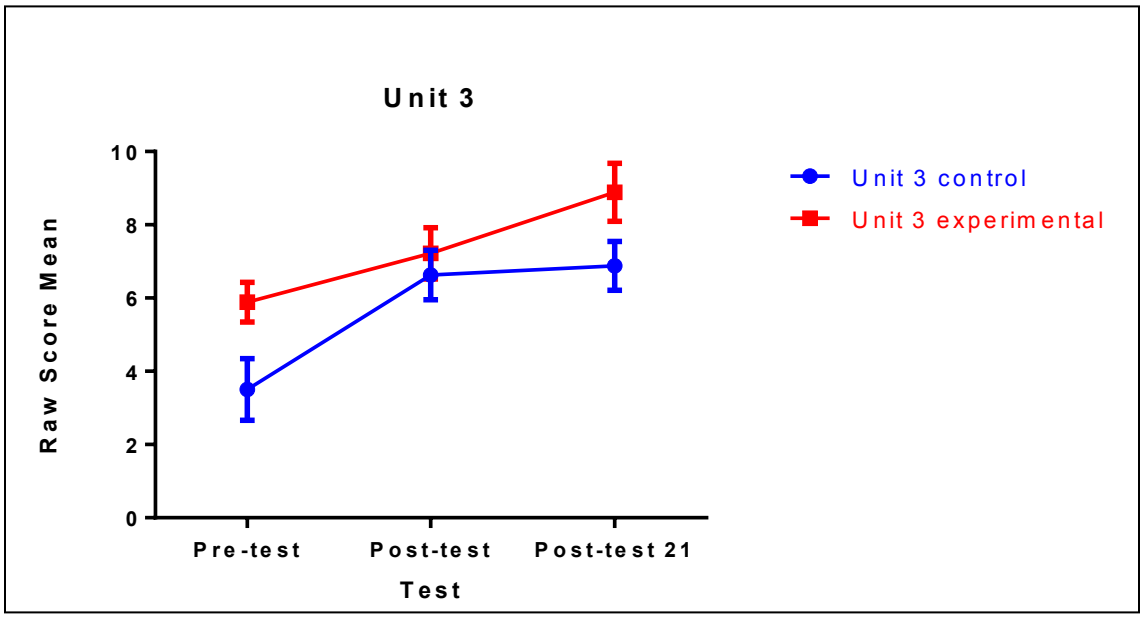

Figure 8. Unit 3: Mitosis Control vs. Experimental Raw Scores.
[Each point represents the average correct score (out of 12 questions) on each of the assessments, with the standard error. The material tested in Unit 3 of the study was from Unit 2 of the biology Louisiana Comprehensive Curriculum, "Reproduction and Genetics", and was explicitly related to mitosis.]

This unit yielded a different result in pre-test to post-test learning gain compared to those of the previous two units. As shown in Figure 9, the control group actually displayed a higher learning gain (NLG=0.305 $\pm$ 0.137) than the experimental group

(NLG=0.220 ± 0.079) from the pre-test to the initial post-test. However, as with the previous units pre-test to 21-day post-test learning gains, the experimental group displayed a higher learning gain (NLG=0.523 ± 0.107) than the control group (NLG=0.360 ± 0.099) from the pre-test to the 21-day post-test (Figure 10). The experimental group not only retained a greater amount of the knowledge, but showed growth from the initial post-test to the 21-day post-test. The learning gains of unit three were the highest of the study, yet did not yield statistically significant differences.

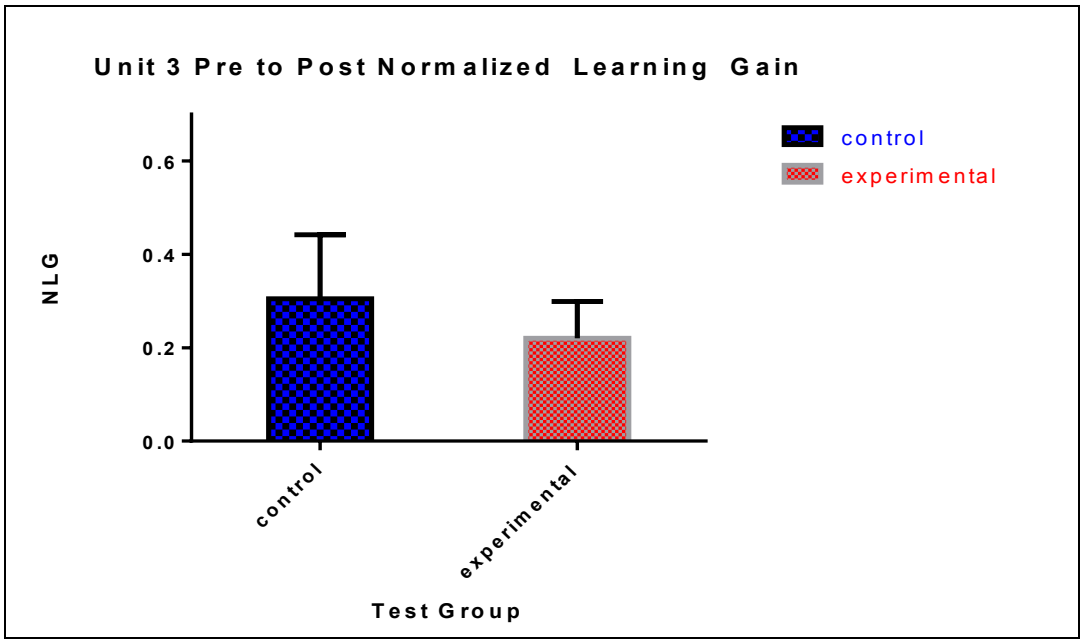

Figure 9. Unit 3: Normalized Learning Gains from Pre-test to Post-test.
[Learning gains were calculated with Slater et al.'s (2001) formula for each student, from pre-test to post-test. These were used to calculate a mean learning gain for each study group, then analyzed with a Mann-Whitney test. This learning gain is the proportion of the material that students learned from the pre-test to post-test as assessed by the post-test.]

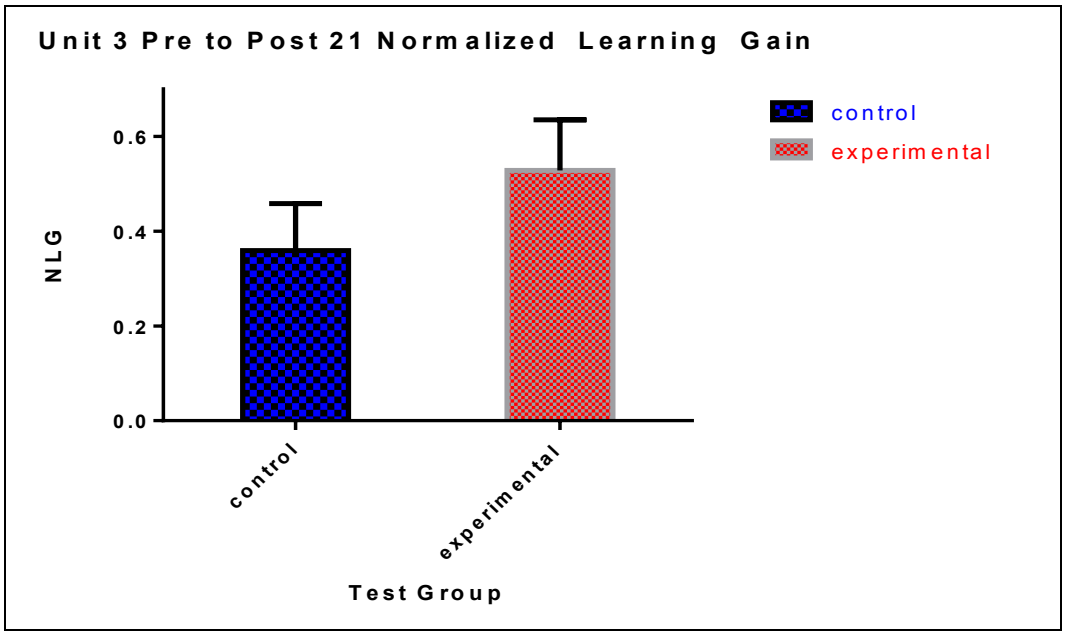

Figure 10. Unit 3: Normalized Learning Gains from Pre-test to 21 day Post-test. [Learning gains were calculated with Slater et al.'s (2001) formula for each student, from pre-test to 21-day post-test. These were used to calculate a mean learning gain for each study group, then analyzed with a Mann-Whitney test. This learning gain is the proportion of the material that students learned from the pre-test to 21-day post-test as assessed by the 21-day post-test. This is the amount of material that was considered "retained" by the student.]

CONCLUSIONS

In each unit of study, the students in both control and experimental groups showed gains indicating learning. Although no statistical significance was found in any of the data, analysis did unveil some trends throughout the units. The use of animations in my biology class did prove valuable as an instructional technique that is both easy to implement and welcomed by students. Because of small sample sizes, the power of the analyses was low reducing the chances of detecting significant differences. Several additional factors need to be noted in consideration of each unit.

For the cellular transport unit, a college-level concept inventory was used as the pre- and post-tests (Odom & Barrow 1995). This test was designed by college professors, and intended for use in undergraduate science courses. Additionally, the test included a second-tier; follow-up multiple choice questions for each initial question in which the test-taker had to rationalize his/her answer to the initial question. For the sake of validity, and in an attempt not to award points to students who simply guessed, points for each first-tier question were only awarded if the student correctly answered the justification "second-tier" question. In retrospect, the questions and test design were likely not age-appropriate for the lower class high school students in this study.

Because concept inventories like that of cellular transport do not exist for protein synthesis or mitosis, other tests were designed for these units. This inconsistency in test design should be noted and considered when attempting to compare learning gains across the three units of study. The availability of test questions, and decision of which to use on pre-/post-tests were large points of concern in the experimental design of this study.

In the event of further study, ExamView test bank questions will be solely utilized, as the software is a supplement to the course textbook, which must be approved by the state department of education prior to use by any public school system. This validates the questions as an acceptable means of assessment to my school and district administration.

In the process of choosing animations for the use of this study, consideration was taken to select age-appropriate material. Animations were chosen for straightforward, less cluttered, style in delivery of the content. It is not completely possible to know if the animations used were the best available for the content addressed. In the future, more time will be taken to research animations for use in the classroom. Additionally, multiple animations may be used to cover a single topic of study.

Another note-worthy aspect of this study was the small sample size due to the small school population. Only one section of Biology Honors was available for study. This limited data for analysis. Initially, I had hoped to compare the data based on gender to see if the effect of animations was possibly greater on one sex or the other. In the sample of 18 students, there were only three males. This was not large enough of a sample size for a meaningful comparison. Another test that was initially considered was to compare gains and raw scores of students who were in the control group in one unit to their own scores in a unit where they were part of the experimental group. Again, the data points were limited in a way that would not have produced any significant data. As the data I did generate indicates that the continued study of animations could be beneficial to my students, these are factors I will consider in future studies. In the event of additional sections of one class, I will use larger samples sizes. Another possibility would be to collaborate with teachers at other schools, either within my parish, or schools

outside the parish where I have colleagues who teach the same subject. Also, additional assessments of same students will provide more data points so the different treatments of animation versus cartoon on an individual student can be compared. I may break the content down within units of study into multiple pre-tests, post-tests, and 14-day post-tests. For example, the Unit one assessment combining osmosis and diffusion could be two sections of study on each topic. In future studies, I also intend to incorporate more units of study. The biology curriculum has many lessons which involve transition and movement, which can be better displayed via animations.

Conclusions of this study were consistent with those of studies on instructional animations found in my research. Stith (2004) saw a significant increase in scores by those students who viewed the animation of 14% compared to scores of students who did not view the animation. In Unit 1 of this study, students who viewed the animation scored 4% higher on the post-test and 6.4% higher on the 21-day post-test than those students who viewed the cartoon. In Unit 2, there was no difference seen between the groups for the post-test. On the 21-day post-test, the experimental group scored 2% less than the control group. In Unit 3, the experimental group scored 5% higher on the post-test and 16.9% higher on the 21-day post-test, compared to the scores of the control group. Despite the lack of statistically significant differences, data from Units 1 and 3 suggest that the experimental treatment contributed to increased learning and retention. Stith did not pre-test the students of his study, thus no learning gains were calculated to which I could compare the gains of this study.

In the 2007 study by O'Day, amount of content retained by students was measured and compared between experimental and control groups. Students who viewed

graphics of apoptosis retained 62% of the content mastered on the initial post-test, assessed by a 21-day post-test. Students who viewed an animation retained 55% of the content mastered on the initial test. In the cholesterol uptake unit of study, students who viewed the graphics again retained 62% of the content, while those students who viewed the animation retained 84% of the content. The influenza virus unit treatment was limited to animation, with which students retained 79% of the content. Students of this study who viewed graphics of osmosis and diffusion showed a retention level of 86%, while students who viewed the animation retained 95% of the content mastered on the initial post-test. Students who viewed graphics on protein synthesis showed a retention level of 102%, due to an increase from the initial post-test to the 21-day post-test. Students who viewed the animation of protein synthesis retained 98% of the content mastered on the post-test. Students exposed to the graphics of mitosis had a retention level of 104%, while students who viewed the animation exhibited a retention level of 123%. Both treatment groups had higher mean scores on the 21-day post-test compared to those of the initial post-test. This study's findings are comparable to the study done by O'Day. In both, trends in two of the three units suggest that animations contributed to increased retention of the material.

Upon completion of this study, students were given surveys to gather opinions on the use of animations in the classroom (Appendix H). Students responded positively, mostly expressing interest in additional units taught with animations. Lessons that the students felt could be improved with the use of animations included blood flow through the heart and body, food webs, the flow of energy throughout trophic levels, and meiosis. Many felt that the animations helped with content retention, as students who viewed them

could visualize them later when taking the 21-day post-test. Students noted they were able to recall the bright colors and movement of the animations, and claimed this helped them to answer questions on content the class had not discussed for some time.

The overall enthusiasm of students' survey responses reaffirmed my opinion that the animations positively affected their learning. Engagement and classroom discussion notably increased. The animations prompted more questions from the students. After the study was concluded, control group students expressed continued interest by asking to view the animations used with the experimental group.

Despite a lack of any statistical significance in analysis of the study data, students enjoyed the experience. Any event of positive response to an instructional method is a valuable asset to a classroom teacher. Students were invested in the study, and looked forward to seeing more of them in lessons. Some positive trends of growth and higher learning gains in experimental groups are an indication that use of animations was successful, and the continued use of animations in future lessons will be worthwhile.

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APPENDIX A: UNIT 1. CELLULAR TRANSPORT PRE-/POST-TEST EXAMPLE QUESTIONS

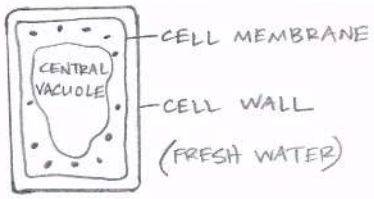


FIGURE 4

11a. Suppose you killed the plant cell in Figure 4 with poison and placed the dead cell in a 25% saltwater solution.
a. Osmosis and diffusion would not occur.
b. Osmosis and diffusion would continue.
c. Only diffusion would continue.
d. Only osmosis would continue.

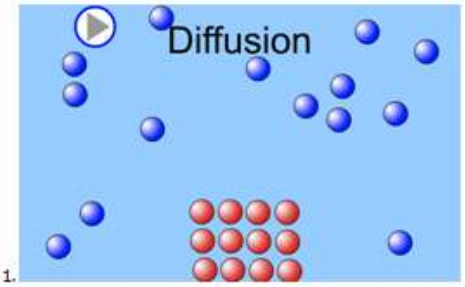
11b. The reason for my answer is because:
a. The cell would stop functioning.
b. The cell does not have to be alive.
c. Osmosis is not random, whereas diffusion is a random process.
d. Osmosis and diffusion require cell energy.

12a. All cell membranes are:
a. semipermeable
b. permeable

12b. The reason for my answer is because:
a. They allow some substances to pass.
b. They allow some substances to enter, but they prevent any substance from leaving.
c. The menibranc rcquircs nutrients to live.
d. They allow ALL nutrients to pass.

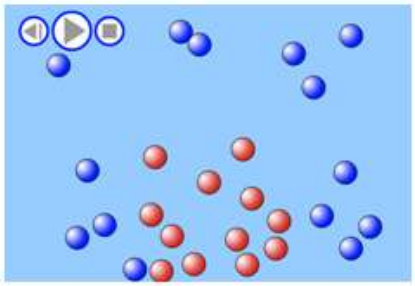
APPENDIX B: UNIT 1. CELLULAR TRANSPORT CARTOONS

1.



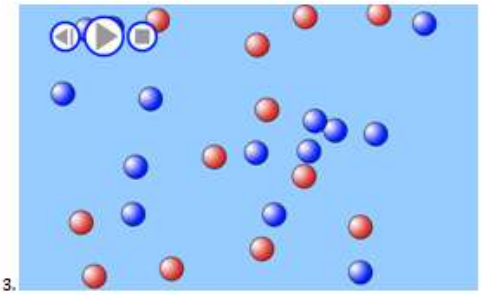
Particles move from an area of high concentration (where there are more of them) to an area of high concentration (where there are less of them). They do this in random movement.

2.



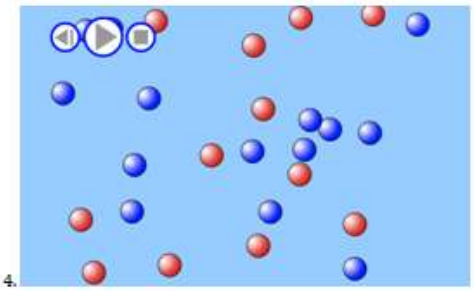
The particles' paths of movement are affected by contact with other particles. The particles will bounce around, even off of each other, until all particles are evenly spread out.

3.



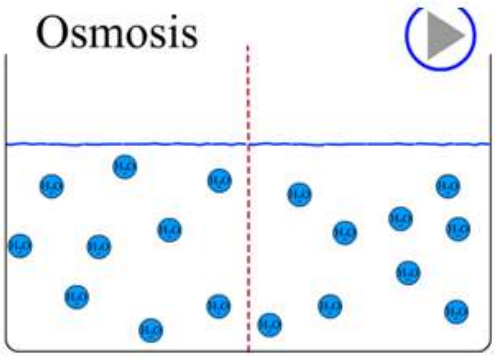
When all of the particles are spaced out, this is called "equilibrium", because the distribution of the particles is EQUAL.

4.



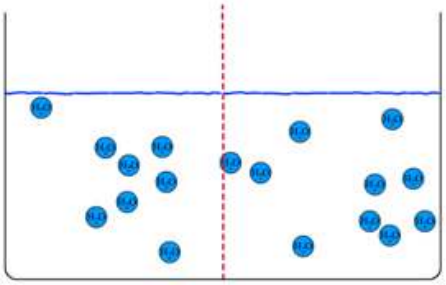
Even after equilibrium is reached, the particles will continue to move (particles are ALWAYS moving). They will just move around more spread out.

1.



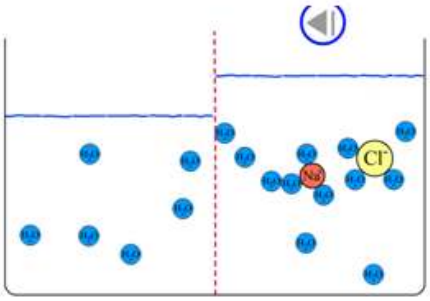
Diffusion of WATER molecules through a cell membrane. It is diffusion so the same rules apply; it's just specific to water.

2.



The water moves freely through the pores of the membrane. Remember, these molecules are moving randomly to achieve and maintain equilibrium.

3.



If a solute (such as salt, NaCl, or sugar) is added, it is too large to move across the membrane. The side with the solute is now hypertonic and the side with just water is hypotonic. The water will flow **from hypo**tonic **to hyper**tonic to achieve equilibrium of water molecules. The water level on the right side will rise.

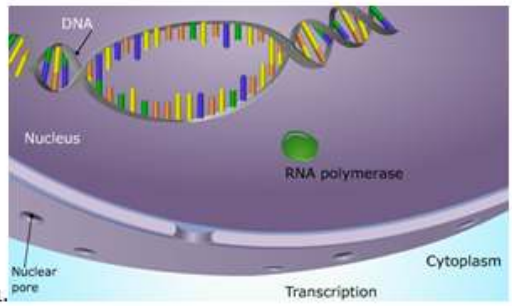
APPENDIX C: UNIT 2. PROTEIN SYNTHESIS PRE-/POST-TEST EXAMPLE QUESTIONS

____ 9.A protein is being assembled when
a. DNA is being translated.
b. RNA is being transcribed.
c. RNA is being translated.
d. DNA is being transcribed.

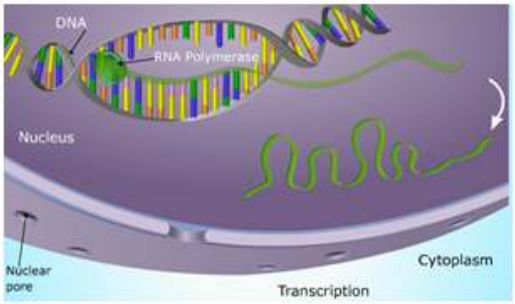
____ 10.Which is the correct sequence of the transfer of information in most organisms?
a. protein to DNA to RNA
b. RNA to DNA to protein
c. DNA to RNA to protein
d. RNA to protein to DNA

____ 11.Which of the following best describes the what happens during gene expression?
a. A cell reads the instructions in DNA and builds a protein based on those instructions.
b. A gene is copied many times so that all of a cell's daughter cells will have their own copy.
c. The nucleus of a cell builds cellular proteins based on the sequence of the mRNA code.
d. A single gene leaves the nucleus of a cell and travels through the cytoplasm to the membrane.

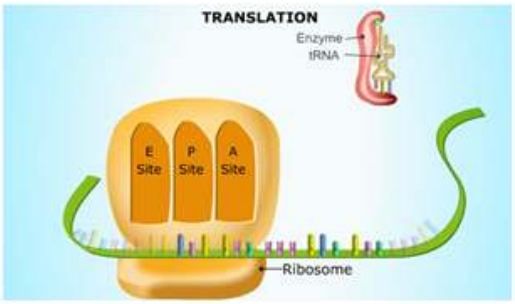
APPENDIX D: UNIT 2. PROTEIN SYNTHESIS CARTOONS



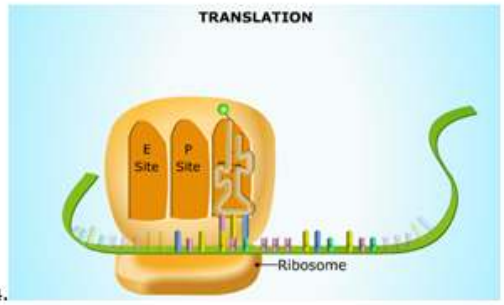
1. Inside the nucleus, double-stranded DNA is unzipped and RNA polymerase regulates the synthesis of an mRNA strand. The mRNA will be complementary to part of one strand of DNA.



2. The mRNA is "transcribed" using the DNA strand, and exits the nucleus through nuclear pores.

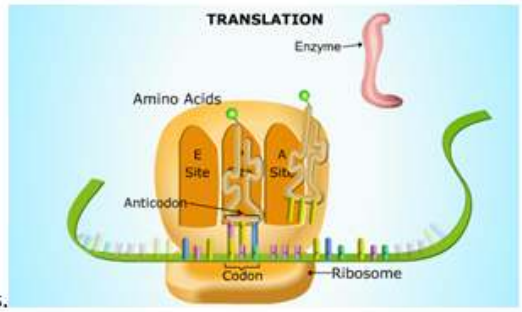


3. The mRNA travels to the ribosomal subunits in the cytoplasm of the cell. During translation, tRNA with anticodons attaches to the mRNA codons to form a string of amino acids.



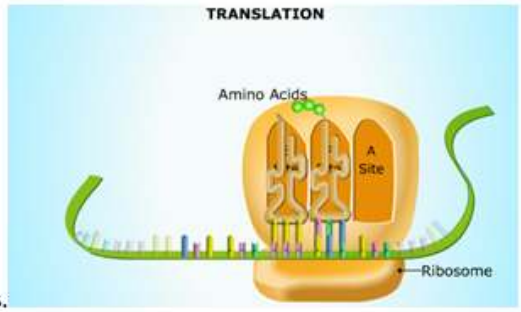
4. The first anticodon will attach to the start codon (AUG) of the mRNA strand.

5.



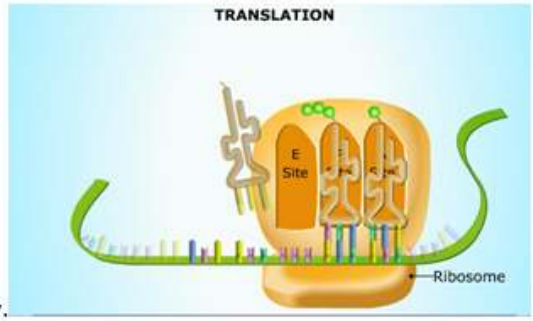
The 1st tRNA molecule slides down the ribosome to make room for the next incoming tRNA molecule carrying the next anticodon. tRNA molecules continue to bind anticodons to corresponding codons on the strand of mRNA.

6.



As new anticodons are joined, the chain of polypeptides or amino acids is formed on the ribosome. This is protein assembly!

7.



The tRNA molecules are released and will continue to deliver more anticodons to the ribosome. The mRNA is "translated" into a polypeptide chain (a chain of amino acids), which makes a protein.

APPENDIX E: UNIT 3. MITOSIS PRE-/POST-TEST EXAMPLE QUESTIONS

____ 1.Which of the following happens when a cell divides?

a. The cell's volume increases.
b. It becomes more difficult for the cell to get rid of wastes.
c. Each daughter cell receives its own copy of the parent cell's DNA.
d. It becomes more difficult for the cell to get enough oxygen and nutrients.

____ 9.During which phase of mitosis do the chromosomes line up along the middle of the dividing cell?

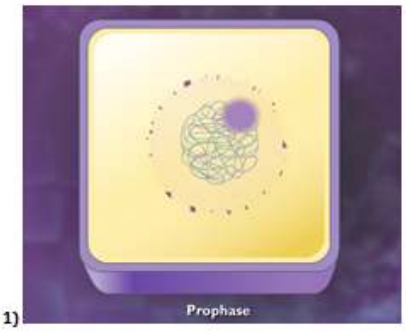
a. Prophase
b. Telophase
c. Metaphase
d. Anaphase

____ 12.During normal mitotic cell division, a parent cell that has four chromosomes will produce two daughter cells, each containing

a. two chromosomes.
b. four chromosomes.
c. eight chromosomes.
d. sixteen chromosomes.

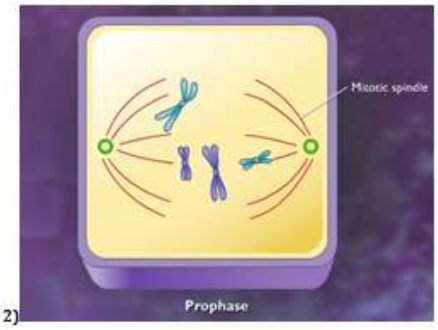
APPENDIX F: UNIT 3. MITOSIS CARTOONS

1)



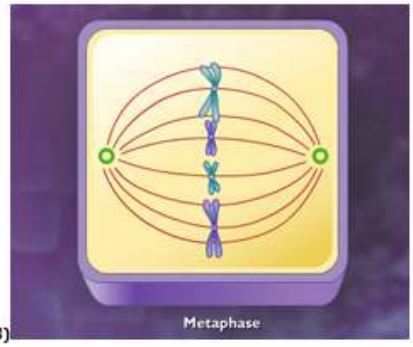
In prophase, chromatin (DNA) condenses into chromosomes. The nucleolus and nuclear membrane both break down.

2)



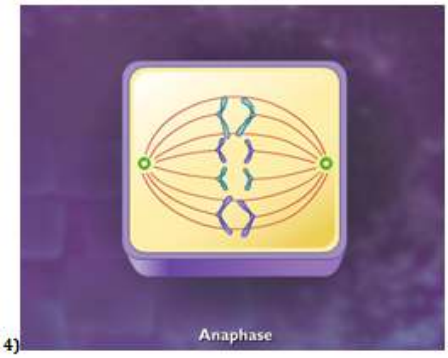
Mitotic spindle fibers begin to form from structures of centrosomes which each contain a pair of centrioles. These centrioles are positioned at the poles of the cell.

3)



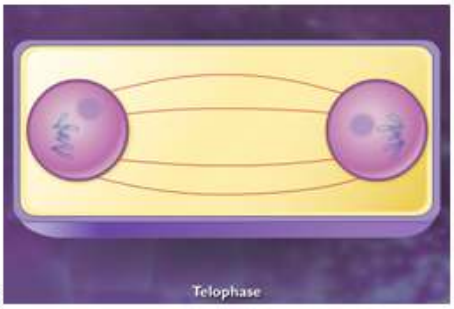
In metaphase, chromosomes are lined up at the center of the cell and spindle fibers are connected to the chromosomes at the kinetochores in the centromeres.

4)



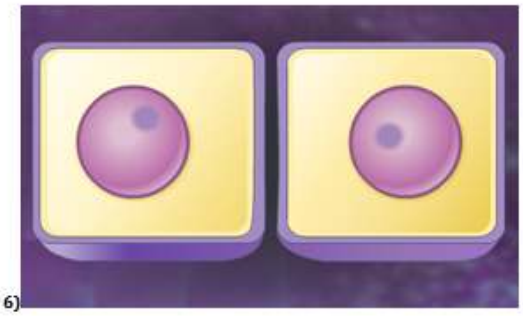
During anaphase, chromatids are separated, as they are pulled apart by the spindle fibers. Spindle fibers attached to chromosomes shorten, as the unattached fibers elongate.

5)



In telophase, 2 new nuclei are visible as nuclear membranes are formed around the chromosomes. The nucleoli become visible again during telophase, and spindle fibers/centrioles disintegrate.

6)



After the final phase of mitosis, cytokinesis must occur for 2 distinct cells to be formed. A cleavage furrow is created in the cytoplasm and moves along the center until 2 identical daughter cells remain.

APPENDIX G: IRB APPROVAL, PARENT CONSENT, STUDENT ASSENT FORMS

Application for Exemption from Institutional Oversight

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

– Applicant,Please fill out the application in its entirety and include the completed application as well as parts A E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html

– A Complete Application Includes All of the Following:
(A) Two copies of this completed form and two copies of part B thru E.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php)
(F) IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator: James V. Moroney **Rank:** Professor

Dept: Biological Sciences **Ph:** 578-8561 **E-mail:** btmoro@lsu.edu

2) Co investigator(s): please include department, rank, phone and e-mail for each
*If student, please identify and name supervising professor in this space

Rebecca Adams Polk, College of Science, Graduate Student (225) 673-3098
rebeccaadams@ipsb.net
Supervising Professor: James V. Moroney

IRB# E5179 LSU Proposal #
✓ Complete Application
✓ Human Subjects Training

3) Project Title: Louisiana Math and Science Teacher Institute

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 6/4/2015

4) Proposal? (yes or no) No **If Yes, LSU Proposal Number**

Also, if YES, either ◯ **This application completely matches the scope of work in the grant**
OR ◯ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) Middle school and high school students

*Circle any **"vulnerable populations" to be used:** (children <18, the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature J. V. M. **Date** 6/1/12 (no per signatures)

**** I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted √ Not Exempted Category/Paragraph 1

Reviewer Mathews **Signature** Robt C Mathews **Date** 6/5/12

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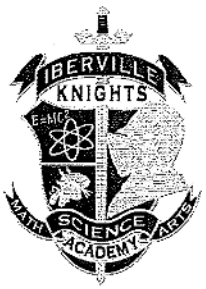

Parents/ Guardians,

As part of my thesis research for the masters program in which I am currently enrolled, I will be carrying out an action research plan in my science classes. The purpose of the research plan is to test effective teaching strategies. Students will be quizzed on content after it is taught, and the quiz results will serve as my data. All student identification and information will be kept confidential. Only the values of the quiz scores will be used to determine if instructional methods have had any effect. Thank you for your usual support.

Rebecca Adams Polk

I give my permission for Mrs. Polk to use the quiz scores of my child,

_____, as anonymous data in her thesis action research plan.

_____ _____

(Parent's name) (Parent's signature)

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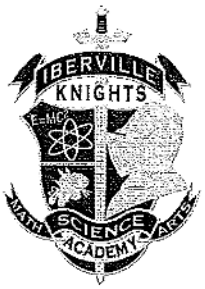

I, _____, agree to be in a study to help determine effective ways for my teacher to teach me Biology content. I will take a pre-test before I am taught the content, and I will take a post-test after I am taught the content. My test scores will not count against me, but I can earn bonus points based on my post-test performance. I can decide to not participate in the study at any time, and will inform my teacher immediately if I decide to do so.

_____ _____ _____
(Student's signature) (age) (date)

_____ _____
(Witness) (date)

Witness should be present for assent process, and not just for signature.

APPENDIX H: STUDENT SURVEY

Survey for Biology – Animations Vs. static cartoons

Which topic did you know the most about before I taught it to you?

A) cell transport (osmosis, diffusion)
B) protein synthesis (replication, transcription, translation)
C) mitosis

Which group were you in for "cell transport"? animation or cartoon?

Use a scale of 1 to 5, 1 being did not help learn the content at all, 5 being helped a lot in learning the content.

The cartoon/animation's effect on you learning the cell transport content.

1 2 3 4 5

Which group were you in for "protein synthesis"? animation or cartoon?

Use a scale of 1 to 5, 1 being did not help learn the content at all, 5 being helped a lot in learning the content.

The cartoon/animation's effect on you learning the protein synthesis content.

1 2 3 4 5

Which group were you in for "mitosis"? animation or cartoon?

Use a scale of 1 to 5, 1 being did not help learn the content at all, 5 being helped a lot in learning the content.

The cartoon/animation's effect on you learning the mitosis content.

1 2 3 4 5

Were there any lessons from this year that you think would be better taught with animations?

Any other comments regarding the animations or cartoons….

VITA

Rebecca Adams Polk was born in Natchez, Mississippi, in 1981. She attended primary and secondary schools in St. Francisville, Louisiana. She graduated from West Feliciana High School in May 1999. She attended Louisiana State University and earned her degree in Biological Sciences with minors in English and Oceanography & Coastal Sciences in May 2007. She entered the Graduate School at Louisiana State University Agricultural and Mechanical College in May 2011 and is a candidate for a Master of Natural Sciences. She has been a middle and high school teacher in Iberville Parish for the past 4 years and is currently teaching middle school sciences, Biology and Advanced Placement Biology at the Iberville Math, Science and Arts Academy East in St. Gabriel, Louisiana.