MODELING DNA STRUCTURE AND PROCESSES THROUGH ANIMATION AND KINESTHETIC VISUALIZATIONS.

By

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ABSTRACT

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There have been many studies regarding the effectiveness of visual aids that go beyond that of static illustrations. Many of these have been concentrated on the effectiveness of visual aids such as animations and models or even non-traditional visual aid activities like role-playing activities.

This study focuses on the effectiveness of three different types of visual aids: models, animation, and a role-playing activity. Students used a modeling kit made of Styrofoam balls and toothpicks to construct nucleotides and then bond nucleotides together to form DNA. Next, students created their own animation to depict the processes of DNA replication, transcription, and translation. Finally, students worked in teams to build proteins while acting out the process of translation.

Students were given a pre- and post-test that measured their knowledge and comprehension of the four topics mentioned above. Results show that there was a significant gain in the post-test scores when compared to the pre-test scores. This indicates that the incorporated visual aids were effective methods for teaching DNA structure and processes.

ACKNOWLEDGEMENTS

My mom, Deb Hager. Her unending support and encouragement throughout the last four summers has been priceless. Without her, I would not have been to complete this enormous feat. Thanks mom. You now have in print that you were right. I love you.

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Introduction

Importance and challenges in teaching DNA and molecular genetics

The importance of understanding molecular genetics is essential for our students. Some of our students will go on to become doctors, pharmacists, biochemists, and drug developers with the potential to make significant gains in developing new drugs, medical diagnostics, treatments, improvements in food production, as well as improvements in forensic techniques. The fundamental understanding of the structure of DNA and the processes associated with it such as DNA replication and protein synthesis will be critical for students to understand in order to tackle these tasks. As Tibell and Rundgren (2010) state, "The rapid progress and potential application of molecular life science have profound implications, not only on our scientific understanding, but also on our future health and prosperity". The majority of our students will not pursue this field, though their understanding will be equally important. Genetics, more specifically genetics research particularly related to biomedical issues, raises a host of important political, economic, and ethical issues. Members of our society must receive a functional understanding of these topics to fully appreciate the questions and answers that these field raises (Marbach-Ad, 2001). It wouldn't be a far jump to assume that the future of human prosperity partially rests on our students' ability to understand how others manipulate DNA as well as the cellular functions that are interdependent on DNA.

If someone were to interview teachers with years of experience teaching biology, many (myself included) would cite molecular genetics as the most difficult unit for students to truly understand. What makes molecular genetics instruction so challenging?

One of the most common barriers cited in teaching this content is the use of domain-specific language. There are many misconceptions that stem from the misunderstanding of certain terms. For example, one study found that students often used the term gene, genetic information, and chromosome interchangeably with little use at all of the word allele (Lewis & Kattmann, 2004). How can students understand the central dogma of biology if they can't understand the terminology used to explain it?

The challenge with domain-specific terminology is three fold. The first is that many terms used in teaching molecular genetics are abstract. These terms lack the ability to relate or form any type of metaphor or connection to words already known by the students. The second challenge is the complexity of scientific jargon. Scientific terms are often abbreviated into acronyms to help facilitate communication among professionals. In the process though, this often confuses lay people, losing them in translation. In molecular genetics, one could make an argument that more acronyms are used for molecules instead of full names. We use DNA to shorten deoxyribose nucleic acid, mRNA for messenger ribose nucleic acid, tRNA to abbreviate transfer ribose nucleic acid, as well as twenty different three letter abbreviations for twenty different amino acids! Finally, the third challenge

lies in the rapidly changing nature of science. As molecular genetics related studies continue to develop rapidly, the meaning of related terms change as new knowledge is generated. The meaning of the word "gene" alone has changed drastically in the last one hundred years with the discovery of introns, overlapping genes, transposons, making a firm and enduring definition difficult to establish (Tibell & Rundgren, 2010).

Another common barrier cited when teaching molecular genetics is the complexity and abstract nature of DNA. Understanding basic biological processes such as DNA replication and protein synthesis becomes very quickly complicated because they occur in three-dimensional space with many events occurring simultaneously (Guzman & Bartlett, 2012). Additionally, these processes are part of complex systems that have several different levels of organization. Scientific phenomena, more specifically biochemical processes are investigated within the macroscopic, microscopic, and mostly in the submicroscopic levels of organization (Schonborn & Anderson, 2006). For example, a process such as protein synthesis starts at a macroscopic level by discussing the purpose of the process in an organism. It then gets discussed at a microscopic level when students learn what structures these processes take place in. When the actual mechanism is being taught, students are learning at the molecular level. In order for students to completely understand these processes, they have to be able to translate between these three levels of organization.

Effectiveness of using visualizations during instruction over non-visualization instruction

Educators have long used visual aids as a tool in tackling the challenges discussed in the previous section. The effectiveness of using visual aids in comparison to teaching biological process through verbal or text instruction alone has been a topic of research (e.g. Starbek, Mensch, Rubba, 2010) thoroughly investigated by the scientific teaching community.

One study by P.Starbek, M. Erjavect, and C.Peklaj (2010) compared the achievement gains in the understanding of transcription and translation using four different groups: a traditional lecture group, a reading text group, a text that supplemented with illustrations group, and a multimedia group that focused instruction around two short computer animations. Using a pre/post test format, they found that the group with text and illustrations, as well as the group with computer animation illustrations, achieved larger gains in acquired knowledge as well improved comprehension when compared to non-illustration groups. In addition, groups that had illustrations had better retention of knowledge when tested five weeks after the instruction was given.

Another study focused on the use of a large hands-on model as a possibly effective visual aid. In a study by David L. Mensch and Pater A. Rubba (1991), both a control group and experimental group received two traditional lecture periods, one on the structure and function of DNA and RNA and another on protein synthesis. The experimental group then received two additional periods, where they worked on

modeling protein synthesis using PVC pipe, rope, Velcro, and other household items. When asked to write an essay detailing the process of protein synthesis, every student in the experimental group attempted the answer and most were able to give accurate and detailed descriptions. In comparison, half of the students in the control group chose not to answer. What students did answer focused more on factual information in isolation rather than an understanding of the process as a whole. This study not only showed better achievement gains with models as visual aids but also demonstrated better attitudes towards biochemistry as a subject.

Visual aids can take shape in a variety of different forms whether it be in static illustrations found in textbooks, animations on Youtube, or hands-on models where student manipulate different pieces. Because of a number of numerous (e.g. Erjavect (2010), Peklaj (2010), Mayer, 1992) studies in addition to the ones mentioned above, it is pretty widely accepted that visual aids, no matter what type, enhance the level of understanding when giving instruction.

Why visual aids increase student comprehension

Visual aids are collectively referred to as external representations by cognitive psychologists because they portray phenomena in the external world, contain spatial relationships, and can be distinguished from internal representations, also termed mental models (Schonborn & Anderson, 2006). Research has shown that well-designed visual tools help students digest large amounts of information in a relatively short time as well as assist in constructing their own internal models (McClean, et al., 2005). In the scientific world,

visualizations are used to communicate knowledge and discovery generated from research, showing what is unseen in the natural world (Rybarczyk, 2011). If students can understand how to interpret scientific representations correctly (which is a necessary skill for navigating media presentations of scientific ideas), it can be used as a learning tool to deepen their understanding.

The importance and value of external representations seems to be associated with Paivio's dual coding theory in association with Sweller's cognitive load theory and Baddeley's model of working memory (Starbek, Erjavect, & Peklaj, 2010). Pavio's dual coding theory explains that humans process information in two different systems: a visual system that processes visual knowledge and a verbal system for processing verbal knowledge. Although they are independent, they are interconnected when the brain encodes, stores, organizes, and retrieves information. The dual coding theory states that learning is enhanced when information is coded both verbally and visually (Zhu & Grabowski, 2005). When students view and interpret graphics pertaining to the content they are learning, it codes visually, enhancing their verbal knowledge from the teacher's lecture.

Sweller's cognitive load theory and Baddeley's model of working memory are both centered on the idea that the brain has a finite amount of working memory. According to Harskamp, Mayer, and Suhre (2007), "…there are three major sources of cognitive load: extraneous processing, which is cognitive processing that is unrelated to the instructional goal and depends on how the material is presented; intrinsic (or essential) processing, which involves basic cognitive processing such as

attending to relevant material and which depends on the difficulty of the to-be-learned material; and germane (or generative) processing, which involves deeper cognitive processing such as organizing and integrating". The goal of using external representations is to reduce cognitive load so that it can increase working memory. Doing this effectively should result in improved learning efficiency and effectiveness (Koroghlanian & Klein, 2004). By using visual representations, not only are students remembering the material in a second way, but they are also increasing their amount of working memory available for learning.

Much of the discussion on visual aids is focused around the assumption that the visual aids being used are of high quality. So what constitutes a "high quality" visual aid from a "low quality of visual aid"? McClean and associates state, "The most effective visualizations reveal the complexity of object involved in the processes, illustrate how and where the objects interact, provide a spatial representation of the molecules during the process, and smoothly represent the transitional states the objects undergo during the length of the process" (McClean, et al., 2005). Additionally in an essay by Schonborn and Anderson (2006), the authors highlight ten criteria for educators to consider when choosing external representations as teaching tools. One of the most emphasized criteria is for the instructor to ensure student knowledge of the visual language and conventions used by the visual aid. This includes a discussion on what symbols or different marks represent in the graphic. Another criterion that is important for instructors to discuss is the limitations of an external representation. Every representation, even

visual aids of the highest quality, lacks some aspect of the content. By discussing these limitations, teachers help to squash misconceptions by the students that may have been generated by the visual aid to begin with. Finally, instructors should use multiple representations to address the same concept. Due to the complexity of biochemical process, any single visual aid lacks the power to show all the aspects of the process. By using multiple representations of the same phenomenon, students start to merge mental models, painting a more detailed and accurate depiction of the process (Schonborn & Anderson, 2006).

Which is a better tool for enhancing student learning: static graphics or animation graphics?

As discussed earlier, it is fairly widely accepted that visualizations of any kind enhance student comprehension. Many educators are now asking, though, if animation is more effective as a visual aid than static graphics, or graphics used in textbooks, worksheets, etc. Numerous studies (e.g McClean, Mayer, Anderson) have been done on this topic and scientists and educators alike still have yet to agree upon the same answer.

Many studies support the idea that animation is a more effective teaching tool than static graphics. In one study by McClean and associates (2005), students were divided into four experimental groups to learn DNA structure as well as DNA replication and protein synthesis. Each experimental group received a traditional lecture followed by an individual study that varied from group to group. The individual study could last up to 25 minutes. In group A, the lecture was presented

first, augmented with animation, and followed by individual study of an animation. In group B, the individual study with text material was completed first followed by a lecture augmented with animation. In group C, the lecture was completed first, which used overheads, followed by an individual study using an animation. In group D, the individual study was completed first followed by a lecture with overheads. The last group acted as the control group with no animation in either session. Using a pre- and post-test format, it was found that Group A, which received animation in both lecture and individual study, performed significantly better than all other groups. Groups B and C, each of which received only one animation treatment, did not perform better than the control group, D, which didn't view any animations. This study supported the idea that animation is effective in teaching protein synthesis if used continuously throughout study. In a similar study done by Mayer and Anderson (1992), comparable results were found. Their results showed that animation containing verbal descriptions enabled students to better solve transfer problems than the students who received static illustrations with the descriptions in print .

Not all studies have found comparable results to the ones described above. There are numerous studies (e.g. Marbach-Ad (2007), Lewalter (2003), Starbek, 2010) published that find no significant difference in the effect of static illustrations when compared to dynamic processes. In a study done by Marbach-Ad et al. (2007) in a college setting, one experimental group received instruction through illustrations while the other received instruction through animation, both

pertaining to the topic of DNA replication and processes. Using the multiple-choice pre and post-test, there was no significant difference found between the two experimental groups. Starbeck and associates (2010) found similar results in a comparable study. The design of their experiment consisted of four groups: two that did not receive any type of visual instruction (either lecture or text) and two that did receive visual instruction (either static illustrations or animation). The results correlated with earlier discussed studies in which the groups that received visual aids performed significantly higher than those that didn't. However, when comparing the static illustrations group to the animation group, there was no significant difference. Another study by Lewalter (2003) measured the impact of both types of visualizations in teaching astrophysical subject matter. His conclusions were similar to previous findings that there was no difference between static illustrations and dynamic animations. Researchers hypothesized as to the explanation of these results. One leading explanation is that students lack the skill to fully comprehend complex visualizations because of their lack of knowledge on the content being presented. Students have very little previous knowledge of the content of the animation. Because of this fact, they can't fully decipher the finer details that are being represented in the animation (Starbek, Erjavect, & Peklaj, 2010).

It is important to note that in two of these three studies discussed, the lack of difference in results between static illustrations and animations were based on a pre- and post-test multiple choice assessment. Two studies did find a significant

difference between these groups in other aspects being studied. Marbach-Ad and associates (2007) found a significant difference between these two groups in the open-ended questions, with the animation group outperforming the static illustration group. The lead investigator noted, "Answers coming from the computer animation group were more accurate and profound than those from the illustration group" (Marbach-Ad, Rotbain, & Stavy, 2007). Starbek and associates found a significant difference between the two groups in terms of both retention of acquired knowledge and retention of improved comprehension. In this case, although there was no significant difference immediately after the completion of instruction, there was a significant difference when tested five weeks later (Starbek, Erjavect, & Peklaj, 2010).

Importance of Supplementary Visual Aids

Static illustrations and animations play a central role in teaching molecular genetics as discussed previously. They are by far the easiest to incorporate into lesson plans, are more accessible to learners, and have a greater repertoire to choose from, when compared to other visual aids such as modeling. It is important to consider other visual aids that can have an equal impact on learning.

Models can play a significant role in teaching molecular genetics. It is generally believed that allowing students to manipulate different cellular parts and molecules used in processes such as DNA replication and protein synthesis helps garner a deeper understanding of what is taking place by activating the kinesthetic learning that many people rely on. Many high school teachers have focused efforts

on developing accurate models to help students understand molecular processes such as protein synthesis, rather than just memorizing a series of "steps".

Ezra Roberg (2004) designed a high school level activity in which Legos ® represent amino acids, with different colored Legos ® analogous to different amino acids (although he typically only uses five different colors instead of twenty). He gave his students the same set of ten Legos ® and asked them to attach them randomly. This demonstrated to students the numerous possibilities of amino acid combinations, (and that's just with five!). He then had his students act out he process of translation by translating a given code. After students have correctly synthesized a protein, he gave them a mutated sequence and asked them to rebuild the protein. This demonstrated the effect of different mutations on amino acid sequence.

High school teachers have also transformed models from tangible objects such as Legos ®to where students act as the model. There are an increasingly number of articles published in which teachers have designed activities where students represent the different molecules and structures used in molecular genetic processes. In an activity designed by Meena M. Balgopal (2010), students acted as DNA, mRNA, tRNA, ribosomes, and golgi apparatuses. They constructed a protein from different amino acids, all of which are a different food item such as marshmallows, cheerios, chocolate chips, etc. Students moved around the room, which represented different areas of the cell, and worked together to construct a protein.

A similar activity designed by Bessie Ong (2010) used wooden hula-hoops and colored balloons to simulate translation. The simulation started with students taping letters on their shirts to represent a DNA sequence. Transcription occurred as free-floating "nucleotide students" matched to the DNA sequence forming the mRNA strand. Students connected hands to represent the bonds that hold nucleotides together. The mRNA strand of students moved the series of hula-hoops that represent different "sites" of the ribosomes while the balloons (each with a name of an amino acid written on it) represent the amino acids. Students acted as tRNA molecules and transported the balloons (amino acids) throughout the different sites on the ribosome to synthesize a protein. Based on a free response pre- and post-test, Ong found that this simulation helped deepen her students' understanding of the process beyond the memorization of the "facts" of protein synthesis.

These role-playing activities are not only being used at the high school level. College professors have begun to integrate them into their teaching methods, including Diana Sturges at Georgia Southern University. Sturges et al (2009) designed an activity to simulate protein synthesis to undergraduate human anatomy and physiology students. Using different colored cards to represent different molecules used in the process, students acted out the process of transcription and translation, with the instructor implementing intentional breaks to use as an opportunity for guided discussion.

Rationale for Study

After teaching biology for several years and collaborating with peers at various professional development opportunities, one common observation continually appeared, which is that one unit in particular, the unit focused around DNA structure and processes, was particularly challenging for students to deeply understand and comprehend. Students do not understand these processes beyond the basic memorization of facts and have little retention of this knowledge after the class is over.

The goal of this study was to determine if using representations that went beyond the use of static illustrations would enhance students' abilities to deeply understand the following four concepts of a DNA unit: DNA structure, DNA replication, transcription, and translation. The hypothesis is that by integrating animation and kinesthetic visual aids into the DNA unit, students would show a significant gain in content knowledge and understanding, as measured by an assessment designed for this study. In order to this test this hypothesis, a combination of models, animation videos, and role-playing activities were developed and incorporated into the unit.

Implementation

Demographics

This study was conducted at Lakeview High School in St. Clair Shores, Michigan. St. Clair Shores is located in the southern part of Macomb County, about sixteen miles northwest of the city of Detroit. According to the 2010 census data, the

city of St. Clair Shores housed approximately 60,000 people. The median household income is $52,755, with 91% of residents age 25 or older earning high school degrees and 23.5% of residents age 25 or older earning a Bachelor's degree or higher. Approximately 9% of the city does live below poverty level (United States Census Bureau, 2013).

Lakeview Public Schools is one of three school districts servicing St. Clair Shores, as well as Lakeshore Public Schools and South Lake Public Schools. Lakeview Public School system is comprised of four elementary schools, one middle school, and one high school. Lakeview High School also participates in the county Career and Technical Education (CTE) program, in which many of our upper level students travel to neighboring schools to receive career education. Lakeview High School also hosts three CTE programs. Lakeview Public Schools is a unique district in the sense that approximately 50% of our students are school of choice students who reside in districts outside of Lakeview Public Schools. Because of this, the city demographics do not align with the district demographics as much as comparable districts throughout the state.

In the 2012-2013 school year, Lakeview High School consisted of approximately 1,364 students. Of those students, 87.2% are white and of Caucasian descent, 7.9% are black and of African-American descent, 1.5% are of Hispanic descent, 1.1% are of Asian descent, and 0.5% of Native American descent. 1.7% of our student population also reported being multiracial, of two or more ethnicities.

In terms of socio-economic status, 68.4% of Lakeview High School students qualify for free or reduced lunch, which is almost double the state average of 36%.

The study was conducted in two general biology sections and one accelerated biology section. At Lakeview High School, biology is the last required science course in the sequence and is primarily composed of juniors, with some advanced sophomores blended in. Of the 93 enrolled students, 72 consented to be in the study.

Overview

Molecular genetics is an introductory course that can be divided into four main topics: DNA structure, DNA replication, transcription, and translation. Traditional instruction was given which included lecture, discussion, interactive reading assignments, as well as static illustration coloring worksheets. Within this traditional format, new external representations were introduced.

Lakeview High School runs a modified block schedule, in which some classes are taught as blocks, which are ninety minutes, and some classes are taught as "skinnys", which are 43 minutes. For the three sections this study was implemented into, all three sections were blocks. The activities listed for each block combined a total 90 minutes of student engagement. Blocks can be further broken down to accommodate the teaching sequence into a traditional 50-60 minute class format.

Table one depicts the sequence of teaching events as well as a time scale in which the activities were completed. Activities in **BOLD** indicate activities of either an animation and/or kinesthetic nature.

Table 1: Teaching Sequence of DNA Unit

Block 1	• Pre-test Assessment • **DNA Model: Part 1** • Lecture: Nucleotide Structure
Block 2	• **DNA Model: Parts 2 and 3** • Discussion: DNA Structure • Activity: DNA Structure Coloring Worksheet • Homework: DNA Replication Interactive Reader
Block 3	• Activity: DNA Replication Brainstorm • Lecture: DNA Replication • Activity: DNA Replication Coloring Worksheet
Block 4	• **DNA Replication Model** • Homework: Protein Synthesis Interactive Reader
Block 5	• Quiz: DNA Structure and Replication • Activity: DNA vs. RNA Coloring Worksheet • Lecture: Transcription • Activity: Transcription Coloring Worksheet
Block 6	• Lecture: Translation • Activity: Translation Coloring Worksheet • Activity: Using a Codon Chart
Block 7	• Activity: SNORK Translation (practices codon chart) • **Discussion: Protein Modeling Project**
Block 8	• **Protein Modeling Project**
Block 9	• **Protein Modeling Project**
Block 10	• **Protein Modeling Project** • Quiz: Protein Synthesis
Block 11	• **Protein Modeling Project**
Block 12	• **Protein Modeling Project**
Block 13	• **Role Play: Protein Synthesis using LEGOS** • Activity: Introduction to Mutations • Lecture: Mutations
Block 14	• Activity: Mutations in Rock Pocket Mice • Activity: Test Review
Block 15	• DNA Unit Test • Post-test Assessment

Descriptions of Key Activities

DNA Model Activity

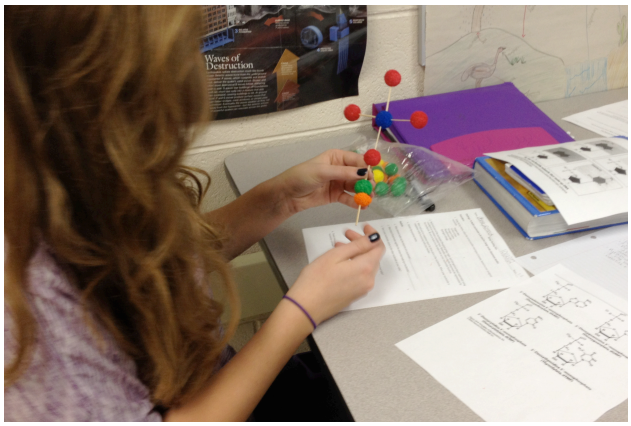
Before this unit started, students had some basic understanding of DNA. From the previous biochemistry unit, students understood that DNA is a macromolecule composed of smaller monomers called nucleotides. Students did not know the structure of a nucleotide, the different types of nucleotides, or any other more elaborate details. They also knew that DNA is linked to heredity and passed down from parent to offspring.

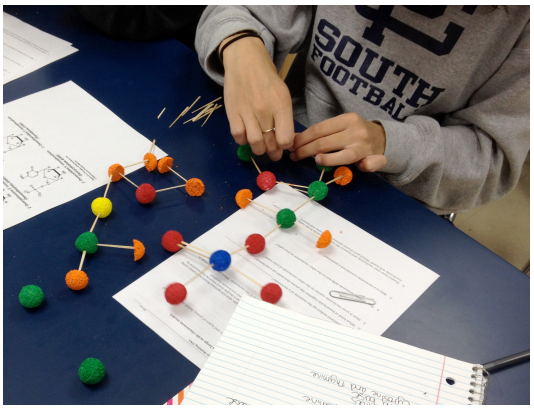
The first activity that integrated kinesthetic learning techniques was a modeling activity that focused on nucleotide structure and DNA structure. Students worked in pairs and received a kit that included various colors of Styrofoam balls and toothpicks. The different colored balls represented different atoms present in the nucleotide. Toothpicks acted as bonds, holding the atoms together.

In part 1 of this activity, students were assigned a nucleotide to construct as a model. The four different nucleotides were evenly distributed throughout the class. They were given a molecular representation of the nucleotide that was assigned to them. Beyond basic instruction on how to connect two atoms together, students were given very little direction on how to build the nucleotide. The teacher, and co-teacher if present, monitored progress and helped when needed. After students completed their nucleotide, an instructor verified its accuracy. If it was not accurate, students were told what was incorrect, asked to correct the mistakes, and have it rechecked for accuracy. Once students had a correct nucleotide structure,

they answered analysis questions (see Appendix A), in which they looked for similarities and differences between their nucleotides and those assigned to pairs throughout the class. After students had finished with the analysis questions, the instructor led a class discussion in which students shared with the class the similarities and differences they observed. This was followed by a brief lecture on nucleotide structure.

Figure 1 shows different points of progress students made while assembling the nucleotides.



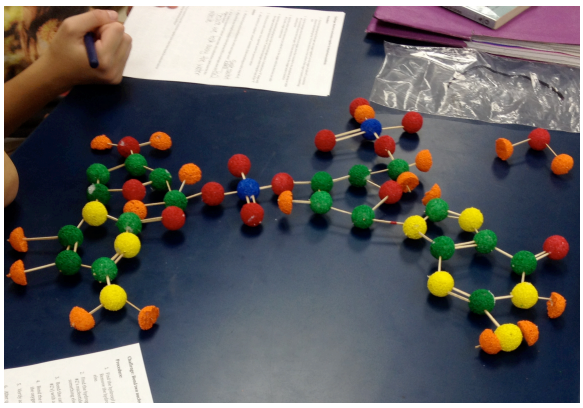


a. Student building a nucleotide. **b. Student building a nucleotide.**

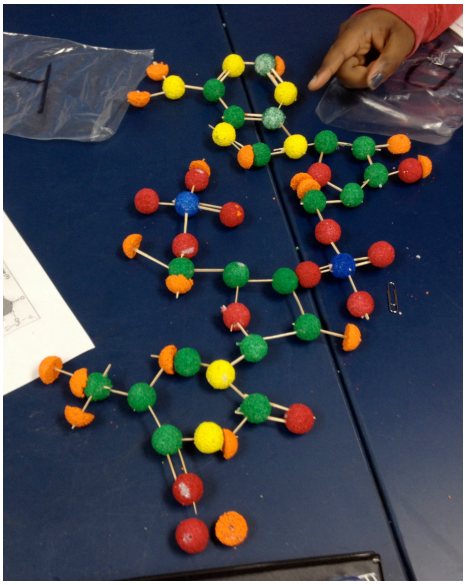
Figure 1: DNA Modeling Activity, Part 1
In figure 1a, a student incorrectly began to construct a deoxyribose sugar next to a phosphate group. In figure 1b, a student accurately built a deoxyribose sugar next to a phosphate group. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

In Part 2 of the DNA modeling activity, students were guided through bonding two nucleotides through dehydration synthesis to simulate how the sugar-phosphate backbones of DNA are formed. Two pairs of students combined from Part 1. Students used written instructions (Appendix A) to guide them through

dehydration synthesis. Once completed, instructors verified accuracy. If the bonding was inaccurate, the instructor worked with each group individually to help correct the errors. Students then completed a set of analysis questions focused on the process of dehydration synthesis and moved on to part 3. Figure 2 depicts two different groups who have bonded the two nucleotides together. In 2a, the nucleotides have been bonded together correctly. The water molecule that is made in the process can also be seen sitting of the side. In 2b, the two nucleotides are bonded together incorrectly. They bonded together the oxygen on the phosphate group of nucleotide to the wrong carbon atom in the sugar on the second nucleotide.



a. Correctly bonded nucleotides



b. Incorrectly bonded nucleotides

Figure 2: DNA Modeling Activity, Part 2

In part 3, students were guided on how hydrogen bonds form between two different nucleotides forming base pairs. Students again worked in a group of four with two models of nucleotides so that a cytosine pair worked with a guanine pair and that an adenosine pair worked with a thymine pair. Similarly to parts 1 and 2,

very little verbal direction was given and students followed a set of written prompts (Appendix A). When completed, the instructor verified accuracy. If the bonds were incorrect, the instructor worked with the group to correct errors after which students answered a set of analysis questions that highlighted the similarities and differences between the two different sets of base pairs. Once part 3 was complete, the instructor guided a class discussion that reviewed the answers to the analysis questions. This was then followed by a short lecture on the overall shape and structure of a DNA molecule. Upon the completion of all discussion, the class took all of the nucleotides and attempted to bond them all together through dehydration synthesis and hydrogen bonds formed through base pairing to form one giant DNA molecule. Three to four base pairs could be put together before the structure became unreliable and started to fall apart.

Protein Modeling Project

This next activity included both animation and kinesthetic learning techniques. Students were asked to model the process of replication of a DNA molecule, as well as the process of making a protein (transcription and translation) through animation. Students were given an option of working alone or with one other partner of their choosing. They were given a time span of three weeks to complete this project. One of those three weeks included 5 dedicated blocks of work time in the computer lab (The equivalent of 7.5 hours). At the start of the assignment, students were given a list a molecules and cell structures that had to be represented in each process (Appendix B). They were also given the rubric at the

start of the project that outlined the criteria used to grade their project. These criteria were: Thoroughness (all molecules and cell structures were represented), Accuracy (molecules and cell structures interacted in the correct sequence of events), Understanding (project conveyed an overall view of how these processes occurred), and Effort and Perseverance (students used all of their class time appropriately).

Many students (38 out of 43 projects) chose stop-forward animation, a digital, technological version of an old-fashioned flipbook. This process begins with finding representations of the required molecules and cell structures. Most students used paper cutouts of nucleotides provided by the instructor in combination with construction paper. In stop-forward animation, students take a series of pictures in which one molecule has been moved slightly from one picture to the next. By taking many pictures, students can show how different molecules move and interact with each other to form a new DNA molecule or a new protein. These pictures are then uploaded into a program such as Windows Moviemaker or Mac's iMovie. Each picture is viewed for a very short period of time (approximately 0.25 seconds). Playing the pictures at such a fast rate makes it look like the pieces are animated.

Some students chose to use other options for this project. Two projects were completed using a paper-pusher technique, in which students record a video in real time. They use their hands to manipulate paper models to show how different molecules interact during DNA replication or protein synthesis (transcription and translation). While they push, they also narrate, describing how the molecules are

interacting with each other. Templates for this project can be found at http://explorebiology.com/apbiology/labs/.

A third option was unexpectedly chosen once this project was assigned and integrated into the class curriculum. Three projects were completed by students that were either currently enrolled in or had been enrolled in Drafting and Design Technology. These projects were completed using a drafting program to animate the process. (Figure 4)

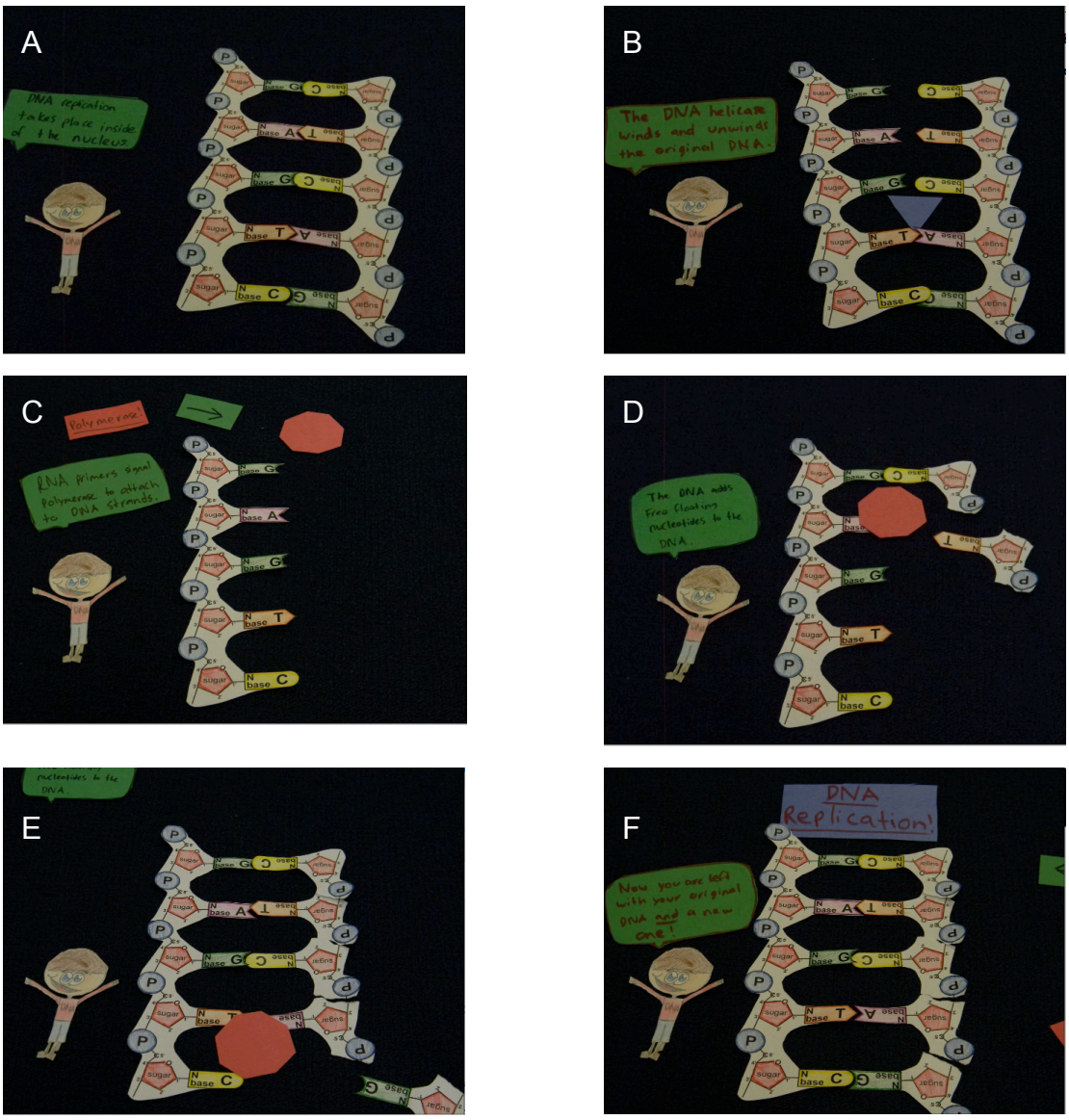


Figure 3: Screenshots of DNA replication in a stop-forward animation video
Figure 3A depicts a DNA model. The dialogue states, "DNA replication takes place in the nucleus." Figure 3B depicts helicase splitting the two strands of DNA. The dialogue states, "DNA helicase winds and unwinds the original DNA." Figure 3C depicts DNA polymerase attaching to the DNA molecule. The dialogue states, "RNA primers signal polymerase to attach to DNA strands." Figure 3D and 3E depict DNA polymerase adding free-floating nucleotides. The dialogue states, "The DNA polymerase adds free floating nucleotides." Figure 3F depicts the final DNA product. The dialogue states, "Now you are left with your original DNA and a new one!"

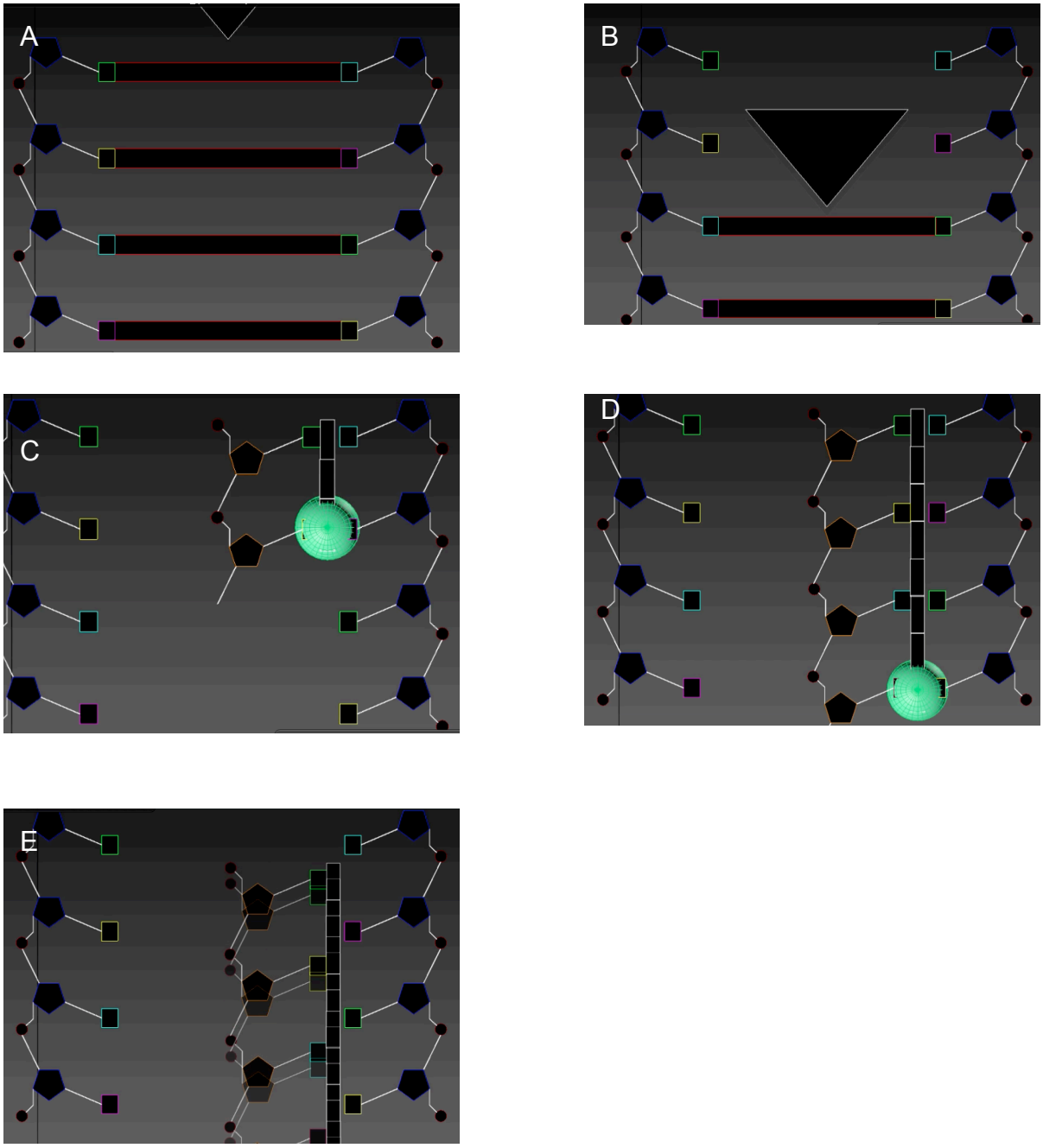


Figure 4: Screenshots of Transcription using Drafting Software
In figure 4A, helicase is preparing to break hydrogen bonds. In figure 4B, helicase is in the process of splitting hydrogen bonds. In figure 4C and 4D, RNA polymerase is adding free floating nucleotides. In figure 4E, the mRNA molecule is detaching from the DNA template.

Protein Synthesis Role Playing Activity

The final activity was one in which students stepped into the roles of the different molecules involved in protein synthesis, more specifically translation. The main learning objective was for students to explain the function of each molecule or cell organelle in the process of translation. The students' goal for this activity was to work as a team to assemble a protein (a block of Legos ®) from amino acids in the cell.

For this activity, the class was divided into two teams (eventually the teams raced to see who could build a protein the fastest). Each person was assigned to be a specific molecule or cell organelle on his or her team. They wore a nametag that hung around their neck to remind themselves and their classmates. Table 2 lists the different roles students filled as well as their function in the process.

This activity was completed in an auxiliary room in the high school that is much larger than a classroom. More space allowed for students to spread out and run, which is much safer than completing the activity in a classroom with desks and other obstacles. Before teams were allowed to work independently, the instructor and class "walked through" an example first. This allowed students to understand what their role as well as their teammates' roles were in the protein synthesis process. Figure 5 outlines how the students were positioned in the room.

Table 2: Explanation of Roles in Role-Playing Activity

Cell Part	Tasks
Lysosome	"Breaks down" proteins that are not correct (either from the cell membrane or a ribosome) and "recycles" organelles that have not done their job correctly.
mRNA	Get instructions for a protein from the DNA and tell a ribosome how to make the protein. The tRNA molecules cannot hear or talk to you.
tRNA	Helps a ribosome by gathering the pieces it needs for a specific protein. You will need to stay near the box containing amino acids.
Ribosome	Gets instructions from the mRNA, tells the tRNA to get the pieces needed, and assembles the protein. Calls for an ER to pick up completed proteins.
ER	Gets a protein from a ribosome and takes it to a golgi body.
Golgi Body	Gets two proteins from two ribosomes and takes the set to the cell membrane. You must have at least two proteins before you can hand them off.
DNA	Shows protein information to the mRNA molecule when it enters the nucleus. The ribosomes and other organelles should not be allowed to see the information.
Cell Membrane	Check the proteins. If correct, pass through the membrane to the teacher. If not, yell for a lysosome to get it for recycling.

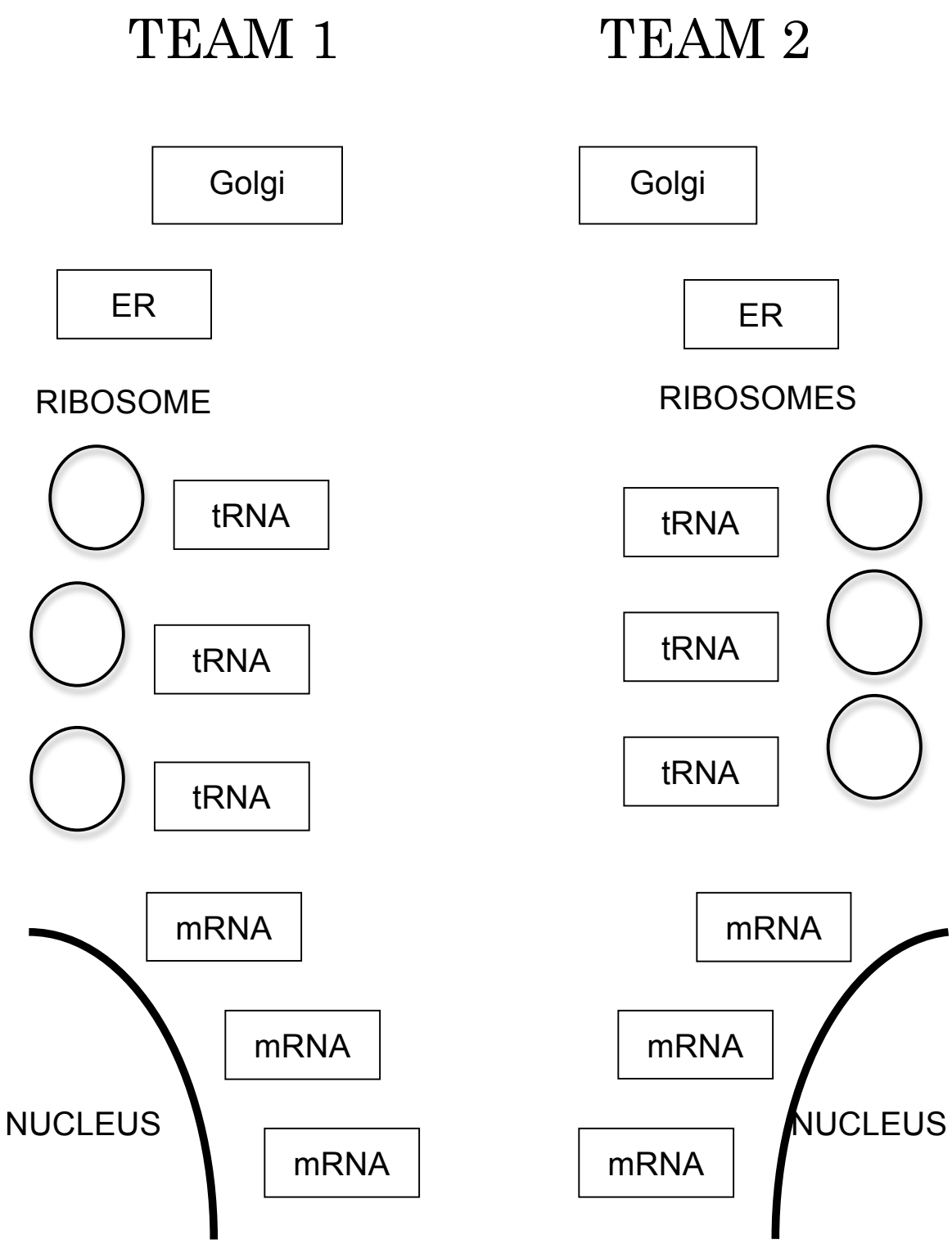


Figure 5: Protein Synthesis Role Playing Map

The activity began by the instructor telling the class their challenge. An example would be to build four different proteins the fastest. After yelling "GO!", the process would begin with the DNA in the nucleus telling an mRNA molecule for which protein it was carrying instructions. The DNA student had a worksheet with eight different examples of completed Legos ® proteins to choose from. Once the mRNA student looked at the completed protein, they would run and describe the different "amino acids" needed to the ribosome student. The ribosome student would tell the tRNA student, which would run to the middle of the room, where a box of amino acids was waiting. The tRNA student would bring back the correct amino acid and hand it to the ribosome student. This process would continue until the ribosome student had attached all of the amino acids together correctly, based on the mRNA student's description. Once the protein was completed, the ribosome student would signal the endoplasmic reticulum (ER) student to come pick it up. The ER student would pass it off to the golgi apparatus student, which would pass it to the cell membrane student where it would be exported out of the cell. Once the protein was exported, the instructor would verify its accuracy. If it was correct, it counted toward to the point total. If it was incorrect, the lysosome student was signaled to disassemble the protein and recycle its amino acids back into the amino acid box.

On one team, one student each represented DNA, ER, the golgi apparatus, the cell membrane, and the lysosome. The mRNA, tRNA, and ribosome roles each had three students representing these roles. Several different rounds were played to

determine which team was more efficient in making proteins. Upon completion, students returned to the classroom and answered analysis questions.

Results

Measurement

A pre-test was given on the first day of instruction at the beginning of the block. A post-test was given on the last day of the unit, after their unit exam. Both the pre- and post-test were graded using the same rubric. Every question was scored on a scale of 0 to 5. Both the assessment and the rubric can be found in Appendix C. For both the pre- and post-test, students were given unlimited amount of time. The tests were completed in class without the help of books, notes, or other students.

Students were assessed using a nine constructed free response questions. The free response questions focused on different content learned throughout the unit. Two of the nine questions focused around the structure of DNA at both a submicro (molecular) as well as a micro (cellular) level of study. Two questions concentrated on explaining the mechanism by which DNA is used as a template to build a new DNA molecule, RNA molecule or a protein. Three questions asked students to apply their knowledge of DNA in a real world context that relates to their life personally. The final two questions asked students to apply their knowledge to predict the effect of a mutation on the protein and/or organism.

Data Analysis

In this study, seventy-two students returned the consent form (Appendix C). Out of the seventy-two students, sixty-seven completed the pretest (n=67) and sixty-nine (n=69) completed the post-test. A one-tailed, unpaired t-test was performed on

each constructed response question as well as the overall score of the assessment, using a function in Excel®. The results of these tests can be seen in Table 3 below. For each question, the maximum score was five.

Table 3: Pre- and Post-test averages, including p-values of DNA Assessment. Maximum score for each question=5, n=69.

Question	Pretest Average	Post-test Average	P-Value
1. What is DNA?	1.27	3.39	6.30×10^{-21}
2. Draw a model of DNA, including as many details as you can.	1.10	4.10	6.00×10^{-39}
3. What kind of information does DNA carry? Includes examples in your answer.	3.09	3.91	0.003
4. What practical uses are there in today's world for the information stored in DNA?	0.65	1.70	1.00×10^{-6}
5. Why is it necessary for a cell in your body to make a new set of DNA molecules?	0.38	2.73	1.80×10^{-22}
6. Explain the mechanism by which a cell makes a new set of DNA molecules.	0.03	2.70	6.22×10^{-18}
7. Explain the flow of genetic information using the following diagram: (Seen in Appendix D)	0.74	3.17	4.32×10^{-23}
8. Albinism, a condition in which a person has little to no skin or eye pigmentation, is frequently caused by a defective enzyme (which is a protein) called tyrosinase. What can cause a protein to become defective?	0.04	1.93	5.48×10^{-14}
9. Is there such a thing as a beneficial mutation? Explain your answer.	0.69	2.74	2.00×10^{-13}
Combined Assessment Score	7.30	26.36	1.09×10^{-29}

As seen in Table 3, the p-values of all questions as well as the combined assessment score are quite small. The largest p-value can be seen in question 3 at 0.003 and the lowest p-value can be seen on question 2 at $6.0x10^{-39}$. All p-values were far below the threshold of significance, which is 0.01. This indicates that the post-test averages were significantly higher than the pre-test averages for all questions as well as the combined assessment score.

Student Surveys

At the end of the unit, students in one section were asked to complete a survey (Appendix C), reflecting on the effectiveness and enjoyment of using animation and kinesthetic activities as a tool for learning. Students were given six different statements and asked to rank each statement on a scale from 1 to 5. A score of one indicates the student strongly disagreed with the statement while a score of 5 indicates that the student strongly agreed with the statement.

Table 4: Student Survey Responses, n=24

Statement	Average Score	Scale Translation by Researcher
1. Animating DNA processes helped me better understand how the molecule involved interacted.	4.42	Agreed
2. I enjoyed the process of creating my own video.	3.21	Neither Agreed or Disagreed
3. The software used to the make the video was easy to learn and use.	3.92	Agreed
4. I would like to use animation as a learning tool in future units.	3.33	Neither Agreed or Disagreed

Table 4 (cont'd)

5. Acting out DNA processes helped me better understand how the molecules involved interacted.	4.46	Agreed
6. I would like to use acting as a learning tool in future units.	3.75	Agreed

As seen in Table 4, the statements that received the highest agreement were the two statements about the effectiveness of these activities in helping the student learn and understand the processes. In terms of looking at individual data, only one student scored one of the statements below a three (Question #1), while in the second question (Question #5), no student ranked the statement lower than a three. In the free response section of these questions, students wrote comments like:

- "The animation DNA process did help me understand transcription and translation better because it show the process in a continuous fashion, and allowed me to watch the process in a simplistic way."
- "This helped to understand the DNA processes better because I am better hands on learner so this helped learn it better."
- "While I was creating my video, I found a lot more information about protein synthesis that I didn't know before. It helped me learn the processes better. "
- "It was hands on and actually made you think instead of just listening in a classroom."
- "Even though I knew what I was doing this made it visually clear. By acting it out, you get a better understanding of how each piece works."

The two questions with the least amount of agreement pertained to the

project in which students created their own animation. The questions referred to the enjoyment that students had creating their own video (Question #2) as well as using animation as a future learning tool (Question #4). In question #2, half of responses, ranked the statement as a 3, neither agreed nor disagreed. This demonstrates that half the class had no particular liking or dislike of the animation project. In question #4, the most frequent response was a 4, agreed, indicating that many students in the class would use animation as a teaching tool again. Although this appears to be positive, this question also received the largest amount of negative feedback. Six students (25%) rated this statement under a 3, indicating a dislike of animation as a teaching tool. The students who did respond negatively to this statement wrote the following comments: "We would be better off watching animations by people who know what they are doing and have time to be more detailed" as well as "I just feel like I learn a lot better though taking notes, listening to lectures, and reviewing".

Discussion

The initial hypothesis of this study was that students would show a significant gain in content knowledge and understanding pre to post instruction after integrating animation and kinesthetic activities into the DNA unit. Based on the results shown in Table 3, the data do indeed support the hypothesis.

By looking at the overall assessment scores, the results show that the post-test combined scores are statistically greater than the pre-test combined scores. The p-value was 1.09×10^{-29}, indicating there is less than 0.01% chance that the pre and

post-test results are the same. The results of this experiment support the findings of McClean et al. (2005), who found that the most effective visualizations "…reveal the complexity of the objects involved in the process, illustrate how and where the objects interact, provide a spatial representation of the molecules in the process, and smoothly represent the transitional states the object undergo during the length of the process." The DNA processes video animation activity includes all of the McClean's required criteria and offer one explanation as to student's success in understanding DNA replication and protein synthesis.

Looking further in depth, the data reveal that two questions with the most significant gains asked students to explain mechanisms by which new DNA is produced (DNA replication) and a new protein is produced (transcription and translation). The average score on a scale of 1 to 5, went from 0.74 to 3.17 on the question about protein synthesis (question #7 on the assessment). The p-value was 4.32×10^{-23}, the second smallest out of all the assessment questions. The result is consistent with the work of Schonborn and Anderson (2006), who studied visual literacy in the field of biochemistry. Their findings support the use of multiple representations as a teaching tool. They state, "…students should be required to interpret multiple ERs (external representations) of the same phenomenon and to merge their mental models of each ER into one unifying model of reality". In this unit, protein synthesis was taught using a wide array of visualizations from static illustrations, to animations (both student generated and non-student generated), to kinesthetic role playing processes. Students saw the same scientific process

presented many different ways and appeared to have successfully merged these different representations into one accurate model.

One of the most telling statistics though is the incredibly low p-value ($6.00x10^{-39}$) of question #2, which asked students to draw a model of DNA. The majority of students scored a 1 (average=1.10) for this question on the pre-test with most of the answers showing a picture of double helix. This is not surprising due to their prior knowledge from 7th grade life science. The post-test average was a 4.10, with only 9% of students earning a score lower than 3. The majority of students (both high and low achieving) were able to draw a nucleotide structure with many being able to connect their nucleotide structure and sequence to a double helix drawing. This was a very happy surprise for the instructor. Historically, this has been one of the hardest concepts for my students to grasp in this unit. In the past, questions pertaining to nucleotide structure are some of the most commonly missed on the unit test. Not only did they perform well on the multiple choice questions pertaining to this topic on the test, but they were able to give sufficient free-response answers as well. This improvement can be attributed to the work in the nucleotide activity. The use of a 3-D model to represent nucleotides made a significant impact in student comprehension. This correlates with the findings of Beltramini et al. (2006) In a similar study, they concluded, "…the visualization of three-dimensional structures of organic molecules, which in itself are attractive and artistic, creates a significant impact on the comprehension of the structure-function paradigm in biology."

It is important to also recognize how these activities impact student engagement, which in turn impact the assessment results. Based on the results of the student survey, it can be concluded that the majority of students liked the animation and kinesthetic activities. As an instructor, I am sure that using these activities increased student engagement compared to the past, in which lecture and static illustrations were used.

The impact of student engagement on student gains in comprehension and knowledge cannot be dismissed as a factor in these results. The positive gains that that student engagement has on achievement results can be linked to the constructivist theory which states that more meaningful learning occurs when students actively select relevant information, organize it into a representation, and integrate it with other knowledge (Starbek, Erjavect, & Peklaj, 2010). In this unit, students were asked to do all of the tasks that comprise the constructivist theory. They selected relevant information to animate the DNA processes and organized it into an animation while connecting to other knowledge they had learned.

In conclusion, integrating animation and kinesthetic visual aids as learning activities to teach DNA structure as well as DNA replication, transcription, and translation, had a positive and significant gain on student knowledge and comprehension. Using these types of visual aids allows students to have multiple models that connect to different learning styles while keeping students engaged in meaningful activity.

APPENDICES

APPENDIX A

DNA Modeling Activity

Name_____Hour_____

Biology-Building DNA

Challenge: To build a nucleotide to be used in a large-scale classroom model.

Procedure:

1. Using the key below, collect the correct number and types of atoms, based on your assigned nucleotide.

   Oxygen=Red
   Carbon=Green
   Nitrogen=Yellow
   Phosphorous=Blue
   Hydrogen=Orange

2. Build each part of the nucleotide (Phosphate group, sugar, and nitrogenous base) separately using a toothpick to represent a covalent bond. Remember that a double bond must be represented by two toothpicks. Be sure to build it on the same scale as your nucleotide handout.

3. When each part is completed, attach the three parts of the nucleotide. When your nucleotide is completed, verify its accuracy with your teacher.

4. Answer the questions below.

Analysis:

1. What element makes up the majority of a nucleotide? _____

2. What kind of bond holds together the atoms that make up a nucleotide?

3. How is your nucleotide similar to the other nucleotide at your table?

4. How is your nucleotide different to the other nucleotide at your table?

5. Why is a nucleotide considered a monomer?

6. Predict how your nucleotide will bond to the other nucleotide at the table. (Which part of your nucleotide will bond? Which part of your partner's nucleotide will bond?)

Challenge: Bond two nucleotides together by dehydration synthesis.

Procedure:

1. Find the hydroxyl group (hydrogen and oxygen together) on the sugar of table #1's nucleotide. Remove the hydroxyl group. This frees electrons in the carbon of the sugar to bond to something else.

2. Find the hydrogen atom located on an oxygen atom that is bonded to the phosphate group on table #2's nucleotide. Remove the hydrogen. This frees electrons on the oxygen atom to bond to something else

3. Bond the carbon with free electrons (on table #1's) to the oxygen with free electrons (on table #2's) with a single covalent bond.

4. Bond the removed hydroxyl group to the removed hydrogen atom. It should form a "V" shape with the oxygen atom being the bottom of the "V" and the two hydrogen atoms being the tops of the "V".

5. Verify accuracy with a teacher. Once approved, answer the questions below.

6. After questions are completed, "unbond" nucleotides. (Undo everything you did in steps #1-4)

Analysis:

1. What kind of bond was formed between the carbon and oxygen atom? _____

2. What molecule was formed by bonding a hydroxyl group (OH) to a hydrogen atom (H)?_

3. If "de" means to remove and "hydrate" means water, why is dehydration a good name for this chemical reaction?

4. If you wanted to bond 400 nucleotides together, how many times would the molecule have to undergo dehydration synthesis?

Challenge: Bond two complementary nitrogenous bases together with hydrogen bonds.

Procedure:

For A-T Tables:

1. Place your nucleotides side by side with the nitrogenous bases in the middle. Then, flip the adenine nucleotide upside down. Use the diagram below to guide you.

2. Using the wire, form two hydrogen bonds.
3. Verify accuracy with a teacher. Once approved, answer the questions below.

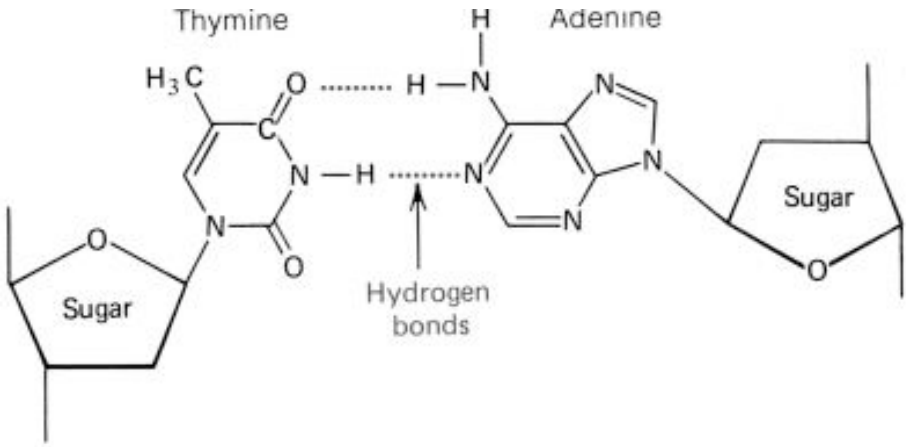


Figure 6: Molecular diagram of an adenosine-thymine base pair

For C-G Tables:

1. Place your nucleotides side by side with the nitrogenous bases in the middle. Then, flip the guanine nucleotide upside down. Use the diagram below to guide you.

2. Using the wire, form three hydrogen bonds.

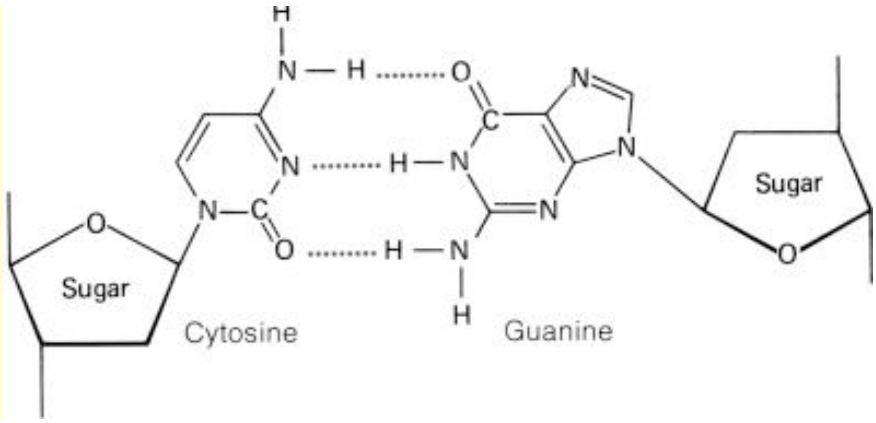


Figure 7:Molecular diagram of a cytosine-guanine base pair

3. Verify accuracy with a teacher. Once approved, answer the questions below

Analysis

1. What two elements can hydrogen form hydrogen bonds to?

   _____

2. What is the hydrogen bonding between adenine and thymine different than the hydrogen bonding between cytosine and guanine?

3. How does hydrogen bonding between nitrogenous bases contribute to the 3-D helix shape that DNA has?

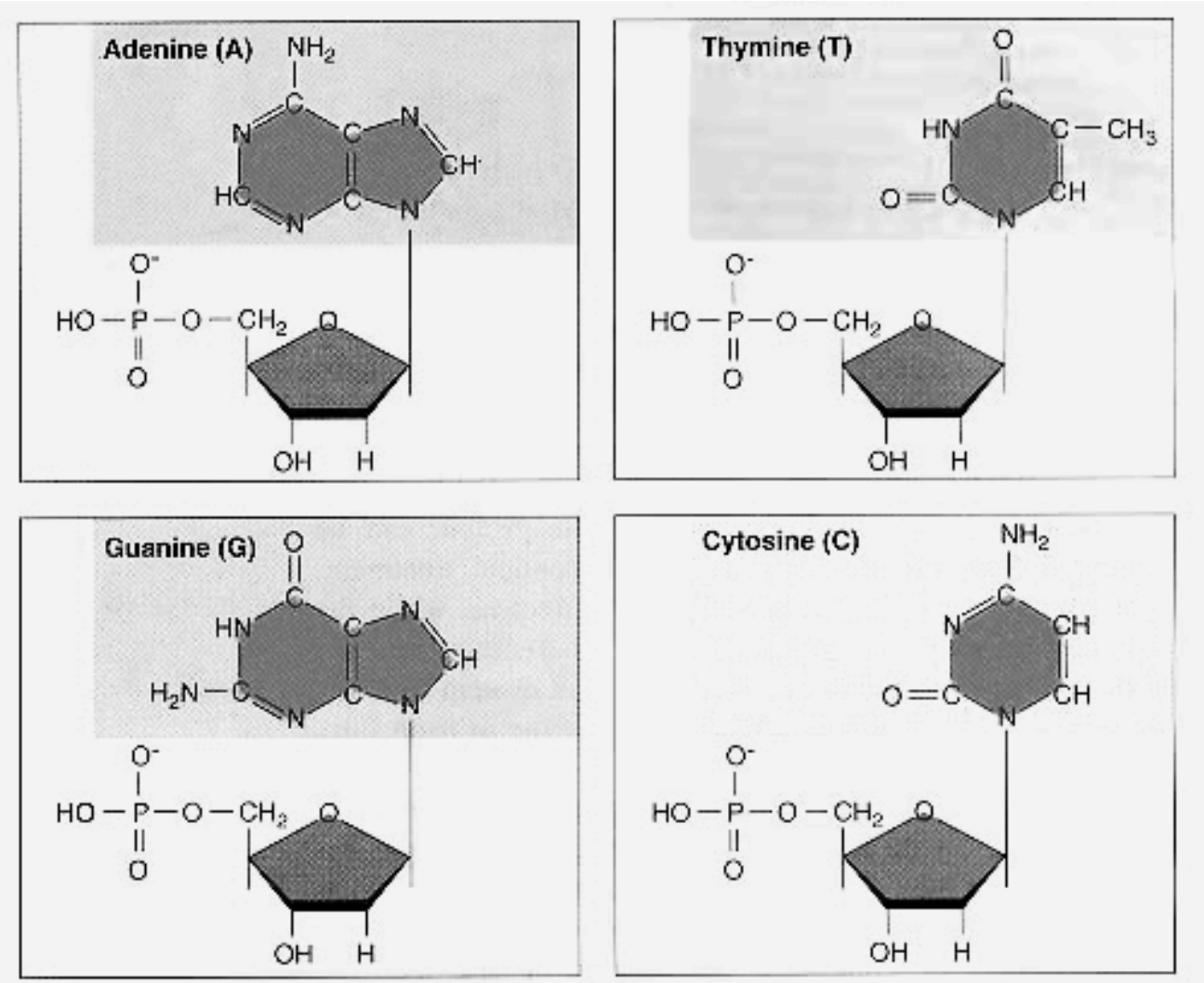


Figure 8: Molecular diagrams of the four different types of nucleotides found in DNA (Source:http://www.nvo.com/jin/homepage20/)

APPENDIX B

DNA Processes Animation Project

DNA Animation Project

Challenge: To create an animation that represents the flow of information from DNA to protein.

1. Choose the method of animation. You may choose from the following ideas:

A. **Stop Forward Video**
   - **Description**: Take a series of pictures in which objects move slightly from picture to picture. Then, create a video in which the pictures are played at a high speed simulating animation.
   - **Required Equipment**: Camera, Software (Movie Maker for Windows, iMovie for Mac)

B. **Paper Pusher Video**
   - **Description:** Film one video that uses the manipulation of paper cut outs (pictures and words) to animate
   - **Required Equipment:** Camera or video recorder, Software (Movie Make for Windows, iMovie for Mac)

C. **Other**
   - **Description:** Pitch a new idea to instructor. It must be approved before proceeding.
   - **Required Equipment:** TBD

2. You will receive **five** in class days to work on your project. During these class days, you can create props, take pictures, record, draw, etc. **You must bring your needed materials to class that day!**

3. The following criteria are **required** to be present in your animation.

Table 5: Required criteria for each process for animation project

Process	Molecules	Location
DNA Replication	DNA, DNA Helicase, DNA Polymerase, Free floating Nucleotides,	Nucleus
Transcription	DNA Helicase, RNA polymerase, Free floating Nucleotides, mRNA,	Nucleus
Translation	mRNA, tRNA, Amino Acid, Protein, Codon, Anticodon	Ribosome/Cytoplasm

Helpful Tips from Ms. Hager to You:

- **Complete each process as we learn about it in class.** Don't wait until the night before to complete the whole video.
- You will have to **put time in outside of class** to complete this project with high quality.
- Although bells and whistles are fun to look at, **accurate and complete content is the most important** part of the project
- Complete your project early so Ms. Hager can look over it.

Table 6: Grading rubric for animation project

Criterion	Beginning (0-4)	Developing (5-9)	Accomplished (10-14)	Exemplary (15)
Thoroughness	Few molecules and locations are accurately represented with major errors in form and function.	Some molecules and locations are accurately represented in form and function with significant errors.	Most molecules and locations are accurately represented in form and function with few, minor errors.	All molecules and locations are accurately represented, in form and function with no errors.
Accuracy	Viewer receives a partially accurate description of one process with little detail and significant error.	Viewer receives a partially accurate description of two processes with some details and significant error.	Viewer receives an accurate description of all three processes with some detail and minor errors.	Viewer receives an accurate description of all three processes with significant detail and no errors.
Understanding	Viewer receives no understanding on how information is transferred from DNA to protein.	Viewer receives little understanding on how information is transferred from DNA to protein.	Viewer receives a broad understanding on how information is transferred from DNA to protein.	Viewer receives a specific understanding on how information is transferred from DNA to protein.
Effort & Perseverance	The students did not finish the project and used little class time effectively.	The students finished the project, but it could have been improved with more effort; Students used some class time effectively.	The students worked hard and completed the project, gave the required effort, and used all class time effectively.	Project was continued until it was complete as the students could make it, gave effort beyond that was required, and used all class time effectively.

Stop Forward Animation for iMovie

Figure 9: This screenshot demonstrates how to start a new project. Open iMovie. From the file menu, choose "New Project".

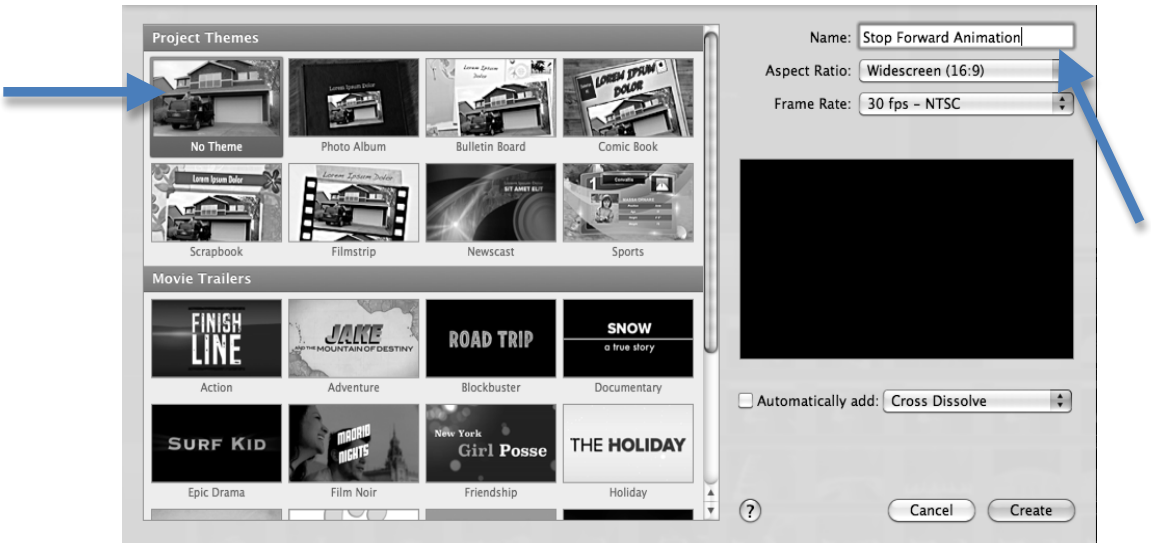


Figure 10: After starting the new project, the program will ask to choose a theme. When prompted, choose, "No Theme". Then, name the project.

Figure 11: Once the project is initially set up, import pictures from iPhoto that will be in the movie. To do this, choose the camera icon on the toolbar in the middle of the screen. Then, click on "Events". Drag the event to the window with the empty frames.

Figure 12: For editing to occur, all frames must be selected. From the Edit menu, choose "Select All".

Figure 13:To begin editing, click on the Inspector button. It is the "I" icon on the middle toolbar.

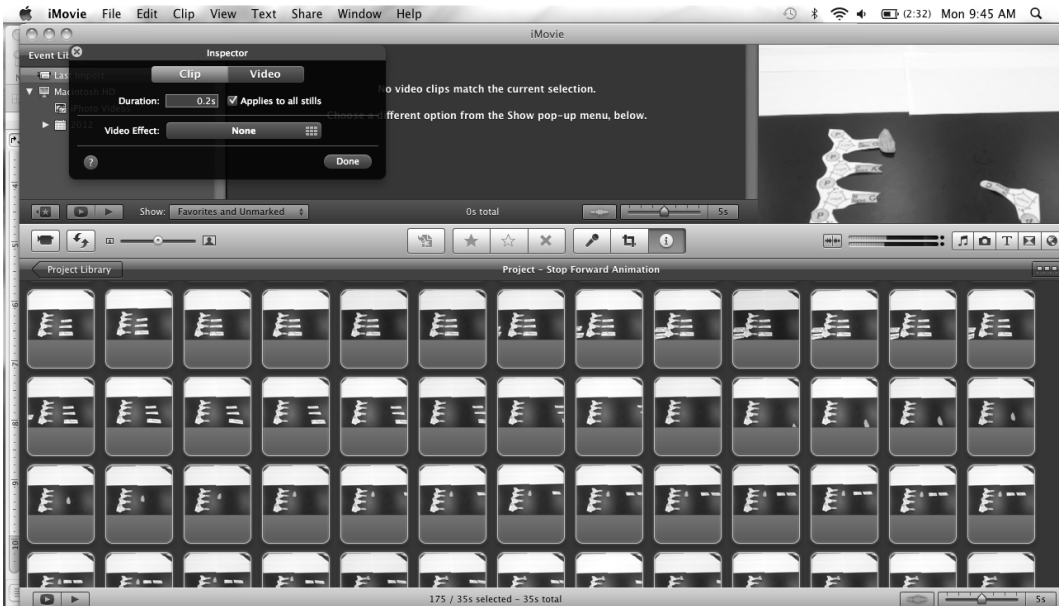


Figure 14: To change the length of duration, type 0.2 in the "Duration" section. Then, select "Apply to all Stills". (This will allow your still pictures to be played at a high speed). Press "Done".

Figure 15: To continue editing, make sure all pictures are still selected (If not, repeat figure 12). To edit the actual picture, click on the crop button. It is located right next to the inspector button.

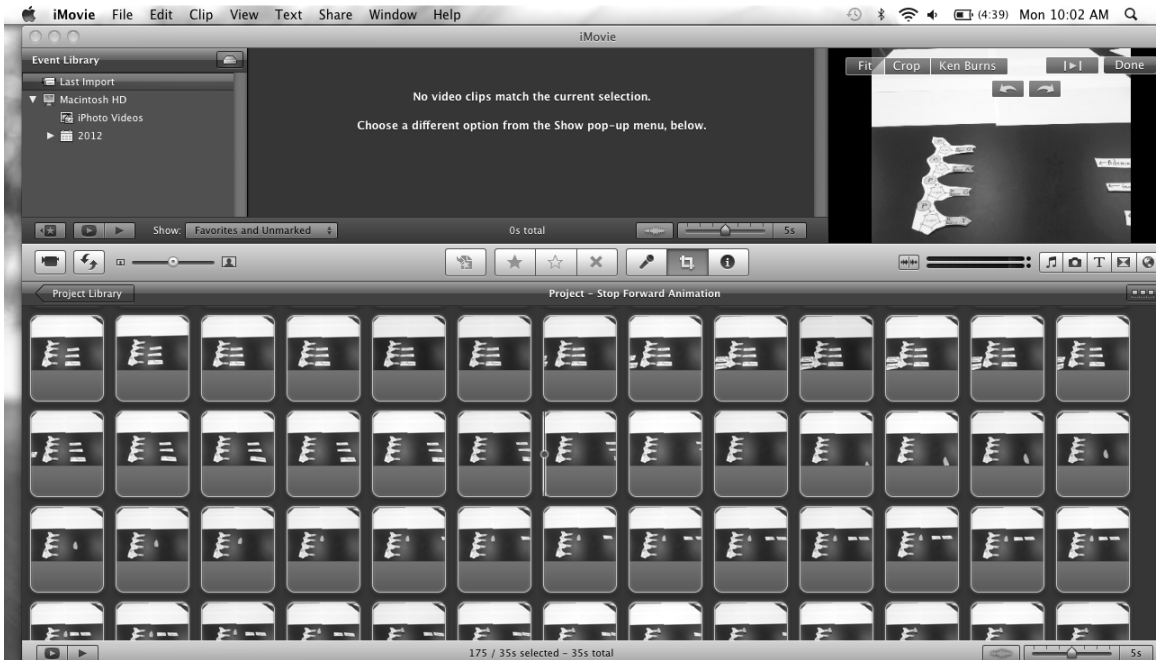


Figure 16: To focus on the picture on the paper cut outs, choose “Fit” and then choose “Done.” Preview movie by pushing play button.

Figure 17: This screenshot demonstrates how to start a new project. Open iMovie. From the file menu, choose "New Project".

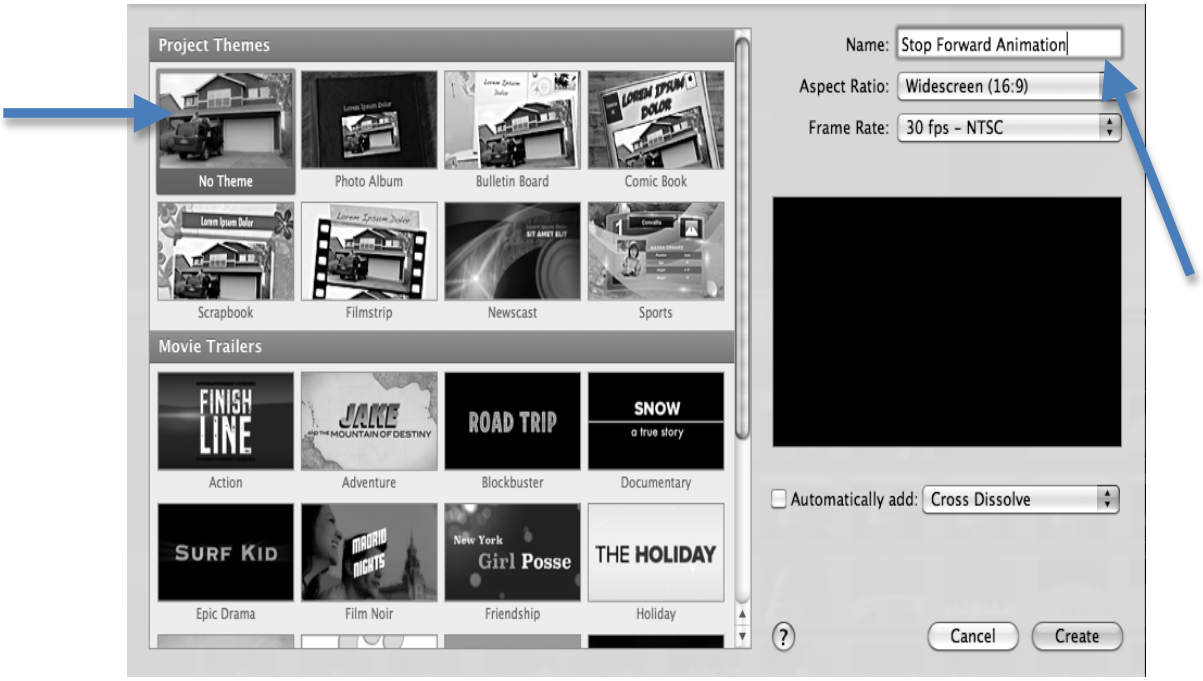


Figure 18: After starting the new project, the program will ask to choose a theme. When prompted, choose, "No Theme". Then, name the project.

Figure 19: To begin the movie, import video from iPhoto. From the File menu, choose "Import...Movies".

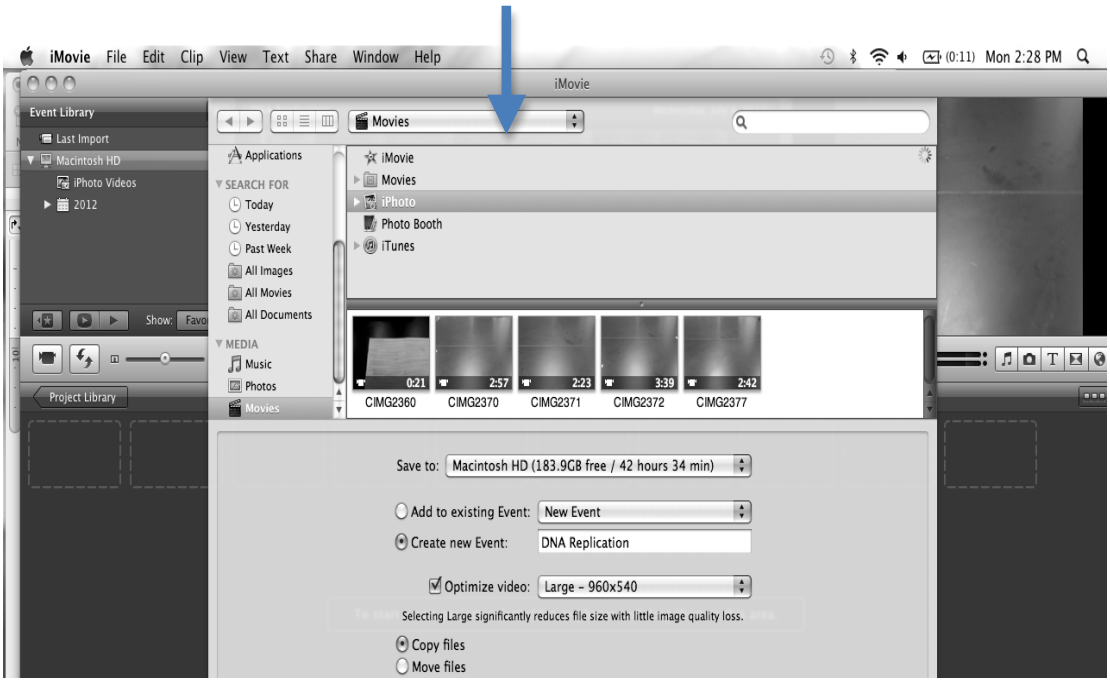


Figure 20:To upload the video, select "Movies" from the side tool bar. Then choose "iPhoto". Select the correct video. Create a new event to place movie in and name it "DNA Replication".

Figure 21: To begin editing, all of the video must be selected. To do this, highlight one frame in the clip. From the Edit Menu, choose "Select Entire Clip". Drag clip below to empty frames.

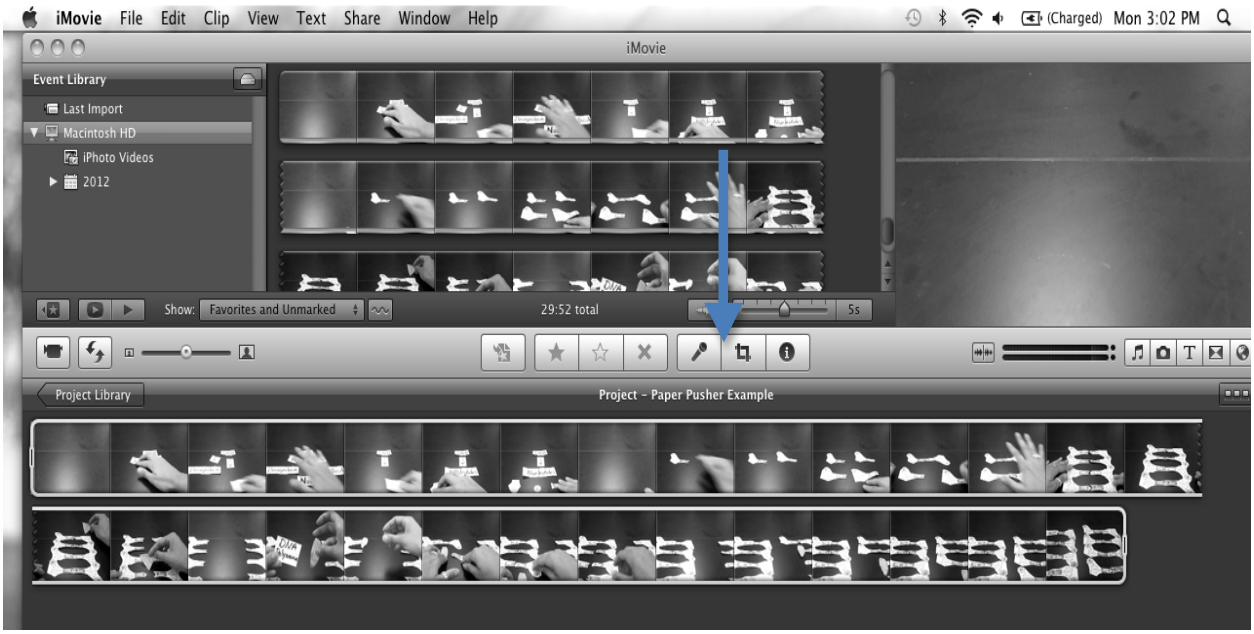


Figure 22; To focus video frame on the paper cutouts, select the entire clip. Press the "Crop" button located in the middle toolbar.

Figure 23: Once the crop button has been selected, choose "Fit" and then choose "Done". Preview video button by pressing play button.

Figure 24: Before making a new video, adjust the settings. This allows the video to have these settings when it is imported. To begin adjusting setting, choose "Options", from the "Tools" menu.

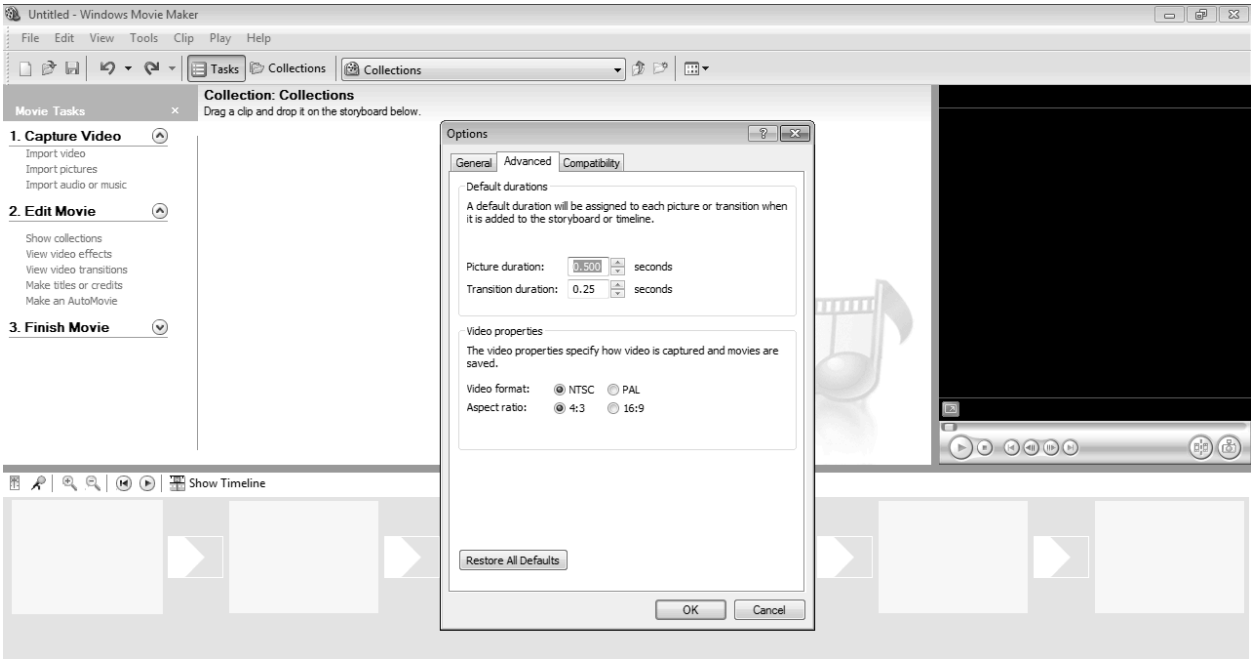


Figure 25: To edit the settings of the picture frame duration, choose the "Advanced" Tab. Then change "Picture Duration" to 0.500 seconds.

Figure 29: Once the settings have been adjusted, choose the correct view setting for the program. The easiest setting to work with is the Timeline setting. To use this setting, choose the "Show Timeline" button located in the middle of the screen.

Figure 30: Now that the settings have been adjusted and the view setting has been chosen, the next step is to start making the movie. To do this, import pictures from a flashdrive.

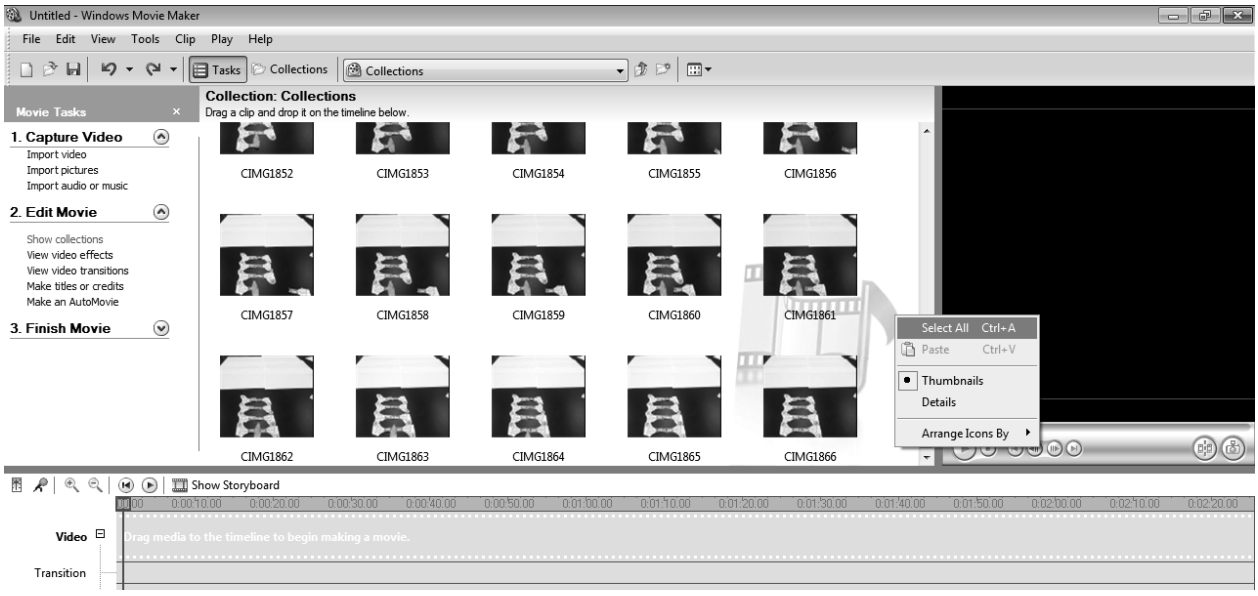


Figure 31: To add imported pictures into the movie, right click in the "Collection Box" and select "Select All". Then drag all of the highlighted pictures and drop in the "Video" box located in the Timeline below.

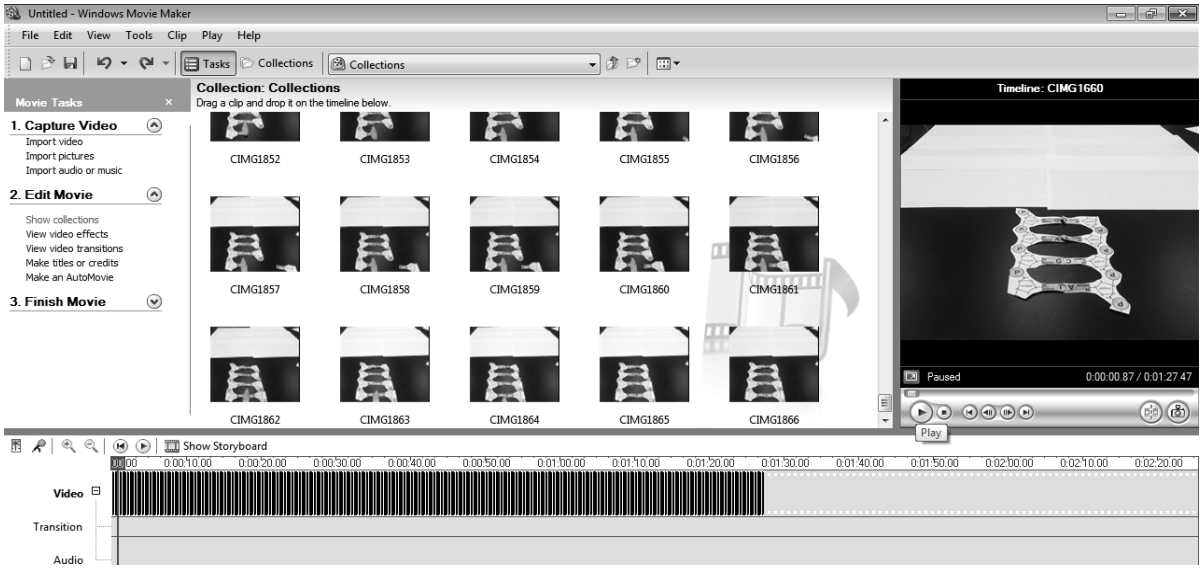


Figure 32: The basic video should now work. Preview the video on the bar to the right.

APPENDIX C

Assessment, Survey, Consent Form

Name_____Hour_____

Biology-DNA Assessment

1. What is DNA?

2. Draw a model of DNA, including as many details as you can.

3. What kind of information does DNA carry? Includes examples in your answer.

4. What practical uses are there in today's world for the information stored in DNA?

5. Why is it necessary for a cell in your body to make a new set of DNA molecules?

6. Explain the mechanism by which a cell makes a new set of DNA molecules?

7.

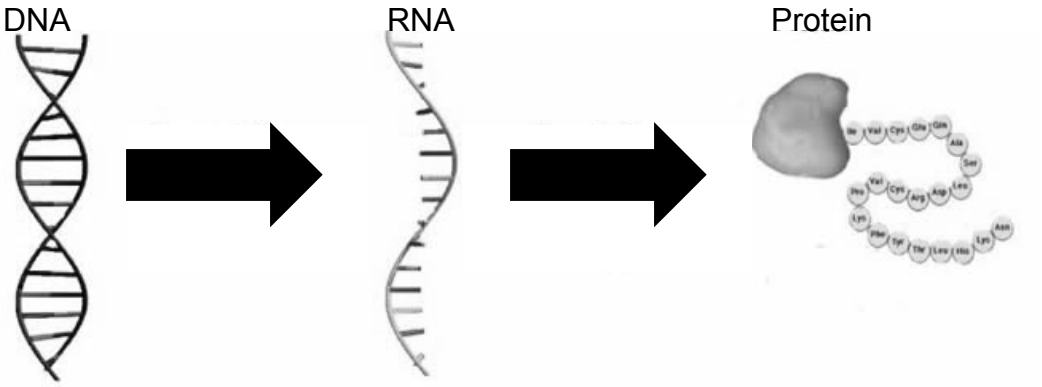


Figure 33: Explain the flow of genetic information using the diagram.

8. Albinism, a condition in which a person has little to no skin or eye pigmentation, is frequently caused by a defective enzyme (which is a protein) called tyrosinase. What can cause a protein to become defective?

9. Is there such a thing as a beneficial mutation? Explain your answer.

Table 7: Grading rubric for pre- and post-test assessment

Question	Beginning (0)	Developing (1-2)	Accomplished (3-4)	Exemplary (5)
#1	Student cannot describe DNA accurately.	Student can identify DNA as a source of genetic information, adding one correct detail to elaborate answer.	Student can describe DNA as a source of genetic information, adding two correct details to elaborate answer.	Student can describe DNA as the source of genetic information, adding three correct details to elaborate answer.
#2	Student cannot model DNA structure or shape.	Student can model part of the structure by identifying nucleotides or a double helix shape.	Student can model structure, by identifying nucleotides and a double helix shape.	Student can model structure in detail, describing nucleotide structure and double helix shape.
#3	Student cannot describe genetic information in DNA.	Student uses little details to describe genetic information in DNA without examples.	Student uses some details to describe genetic information in DNA, including 1 example.	Student uses many details to describe genetic information in DNA, including 2 examples.
#4	Student cannot describe any uses for DNA.	Student can describe one use for DNA.	Student can describe two uses for DNA.	Student can describe three uses for DNA.
#5	Student can identify or describe DNA replication as part of the cell cycle.	Student can identify DNA replication as a necessary part of the cell cycle with little detail.	Student can identify DNA replication as a necessary part of the cell cycle with some detail.	Student can describe why DNA replication is a necessary part of the cell cycle with detail.

Table 7 (cont'd)

#6	Student cannot accurately describe DNA replication.	Student can describe parts of DNA replication but with significant error.	Student can accurately describe DNA replication with minor errors.	Student can accurately describe DNA replication including semi-conservative replication without error.
#7	Student does not use diagram to describe transcription and translation.	Student uses diagram to describe transcription and translation with few details and significant error.	Student uses diagram to accurately describe transcription and translation with some details and minor errors.	Student uses diagram to accurately describe transcription and translation with many details and no errors.
#8	Student cannot identify or describe a change in amino acid sequence.	Student identifies an abnormal amino acid sequence but cannot connect it to DNA sequence.	Student identifies an abnormal amino acid sequence and can identify its origin in DNA sequence.	Student identifies an abnormal amino acid sequence and can describe its origin in DNA sequence.
#9	Student incorrectly identifies it as impossible.	Student accurately identifies it as possible but cannot justify their explanation.	Student accurately identifies it as possible and can justify their explanation with some detail.	Student accurately identifies it as possible and can justify explanation with detail and including an example.

Rate the following statements on a scale of 1 to 5. Please provide a brief explanation for each choice.

1=Strongly Disagree
2=Disagree
3=Neither Agree or Disagree
4=Agree
5=Strongly Agree

1. Animating DNA processes helped me better understand how the molecules involved interacted. _____

2. I enjoyed the process of creating my own video. _____

3. The software used to make the video (Moviemaker or iMovie) was easy to learn and use. _____

4. I would like to use animation as a learning tool in future units._____

5. Acting out DNA processes helped me better understand how the molecules involved interacted. _____

6. I would like to use acting as a learning tool in future units._____

PARENTAL CONSENT AND STUDENT ASSENT FORM

Dear Students and Parents/Guardians:
I would like to take this opportunity to welcome you back to school and invite you to participate in a research project, Modeling DNA Structure and Processes through Animation and Kinesthetic Visualizations, which I will conduct as part of biology this semester. My name is Ms. Christine Hager. I am your biology teacher this semester and I am also a master's degree student at Michigan State University. Researchers are required to provide a consent form like this to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

What is the purpose of this research? I have been working on effective ways to teach DNA structure and processes, and I plan to study the results of this teaching approach on student comprehension and retention of the material. The results of this research will contribute to teachers' understandings about the best way to teach about science topics. Completion of this research project will also help me to earn my master's degree in Michigan State University's Division of Math and Science Education (DSME).

What will students do? You will participate in the instructional unit about DNA structure and processes. You will complete the usual assignments, activities, class demonstrations, and pretests/posttests just as you do for any other unit of instruction. There are no unique research activities – participation in this study will not increase or decrease the amount of work that students do. I will simply make copies of students' work for my research purposes. This project will continue from October to November. I am asking for permission from both students and parents/guardians (one parent/guardian is sufficient) to use copies of student work for my research purposes.

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

What are the potential risks? There are no foreseeable risks associated with completing course assignments, activities, class demonstrations, and pretests/posttests. In fact, completing course work should be very beneficial to students. Another person will store the consent forms (where you say "yes" or "no") in a locked file cabinet that will not be opened until after I have assigned the grades for this unit of instruction. That way I will not know who agrees to participate in

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

What are your rights to participate, say no, or withdraw? Participation in this research is completely voluntary. You have the right to say "no". You may change your mind at any time and withdraw. If either the student or parent/guardian requests to withdraw, the student's information will not be used in this study. There are no penalties for saying "no" or choosing to withdraw.
Who can you contact with questions and concerns? If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher Christine Hager: chager@scslakeview-k12.com; 586-445-4045 and /or Dr. Merle Heidemann: 354 Farm Lane #118 East Lansing, MI 48824; heidema2@msu.edu; 517-884-3468].
If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

How should I submit this consent form? If you agree to participate in this study, please complete the attached form. Both the student and parent/guardian must sign the form. Return the form to Ms. Givinsky in room 209 by September 14th.

Name of science course: Biology
Teacher: Ms. Hager
School: Lakeview High School

Parents/guardians should complete this following consent information:

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

Please check all that apply:
Data:
_____ I give Ms. Hager's permission to use data generated from my child's work in this class for her thesis project. All data from my child shall remain confidential.
_____ I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of their participation in this research.
Photography, audiotaping, or videotaping:
_____ I give Ms. Hager's permission to use photos, audiotapes, or videotapes of my child in the class room doing work related to this thesis project. I understand that my child will not be identified.
_____ I do not wish to have my child's images used at any time during this thesis project.

Signatures:

_____ _____
(Parent/Guardian Signature) (Date)

I voluntarily agree to participate in this thesis project.

_____ _____
(Student Signature) (Date)

*****Important*****
Return this form to Ms. Givinsky in room 209.

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