Spring 4-19-2016

Animations and Diagrams in Virology: Their Effects on Student Learning

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Animations and Diagrams in Virology: Their Effects on Student Learning

By

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A Portfolio Collection submitted in partial fulfillment of the requirement of the

University Honors College at Kennesaw State University

Kennesaw State University

April 20, 2016

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Acknowledgements

To Jennifer Louten, Ph.D., for providing the opportunity to grow as an illustrator and animator, and to develop in my abilities in working with a client. Thank you for your encouragement, support, and excitement when I show you my work. Thank you for being a good friend and mentor. And to Michael Lahey, Ph.D., Laura Palmer, Ph.D., and Kami Anderson, Ph.D., for your assistance.

To everyone who participated in the study.

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Abstract

The contrast in the manner that students receive and interpret information has been a topic of conversation for years. It has been widely debated whether or not the addition of animations have any benefit to a student's learning and grades. This study was conducted to discover if students learn better, in the context of Virology, from animations or diagrams when presented new information. Participants were chosen from students who attended Kennesaw State University. They were asked to meet in a classroom setting and presented either three animations or diagrams then asked to answer questions on what they had been shown. The results of this research were that students performed better after having had seen the animations. This paper discusses these findings and how they will apply to the educational system.

Animations and Diagrams in Virology: Their Effects on Student Learning

Mary Reynolds

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Introduction

This thesis seeks to determine if students learn better from animations or diagrams especially when concerned with science and specifically with Virology - the study of viruses. The hypothesis is that students will learn better from animations. Students learn in different ways (Alessi 2011), but what is the best method to reach them in the classroom? This research was conducted to understand how students learn in a classroom setting when presented with information in the form of multimedia. The goal of the study was to provide context for teachers to adapt their classrooms in a means that would benefit the overall learning experience for students.

The thesis project started when Dr. Jennifer Louten needed someone to illustrate the textbook that she was writing. Dr. Louten suggested that animations be made for teachers who bought her textbook to have extra material to teach their students with. After some refining and deliberation, the hypothesis was decided on and the research began. Most majors were allowed because we assumed they lacked bias. It was thought that science and art majors should not be allowed to participate in the study because art majors typically prefer animations and science majors would be more likely to understand what was going on because it was closely related to their field. We approached many majors though most ended up being engineering majors. Two-thirds of the participants were engineers since a significant portion of the Marietta campus of Kennesaw State University is comprised of engineering-based majors. This allowed for a decent means of finding participants.

The study had 45 college-aged participants ranging in age from 18 to 34. Most were younger than 24 but there were two participants over the age of 30 who are still in college. In order to find participants, various professors were emailed and asked to inquire if their students would be willing to participate in the study. Acquaintances of the author who fit the guidelines for participants were asked to take part as well. Discussed next in this paper will be the Literature Review, Methodology, Results, Summary, and then the Conclusion. This order was found

beneficial for what is being conveyed. The diagrams and animations discussed in this thesis are located in the Appendix for reference.

Literature Review

This thesis covers whether students learn better from animations or diagrams when presented new information. The following section compares the findings of this paper with others like it. When researching similar studies for this topic, it was discerned that a decent amount of studies concluded animations are not helpful to students (Morrison, 2000; Hegarty, 2003; Adamczyk, 2009; Höffler, 2010). These papers range from saying that the animations have no significant impact on the students at all to students simply appreciating the supplemental material. However, more recent studies have found that animations are becoming progressively more important in the education system. When researching animation in classrooms during the early stages of incorporation, Ploetzner and Lowe (2012) believed that this style of learning would likely become a prominent way of presenting information to students. Research by Henriksen and Neppl (2014) discusses how animations are helpful to students due to the inability of 2D images and diagrams to provide sufficient information to students. Their findings agree with that of this study that students enjoyed the animations and gained better test scores because of them. A study by Johnson, Ozogul, and Reisslein (2015) was conducted to see how students learn when they are exposed to new information as well as when they have no prior knowledge of the subject. They observed that animations did not aid students with prior knowledge as much as those without. These results reiterated the exclusion of science-based majors in this study. When working with English as a Foreign Language students, Niknejad and Rahbar (2015) became aware that the students understood what they were being taught more from animations than from still images. Moreover, Zahra (2016) gathered that the students in his study benefited from the animations they were shown. The significance to note here is the blatant shift in results from the early 2000s to now. As technology has progressed, so has the reliance on it. Before, it was rare to have a computer in a classroom and now students are encouraged to bring their laptops to school to take notes. Therefore, the results of this study and many others like it validate the utilization of that dependence and the incorporation of advanced media in the classroom. The next section will discuss the methodology of the research.

Methodology

This thesis was completed to understand how students learn and to see if they would prefer animations or diagrams in the classroom setting when presented with new information. In this section the participants, materials, and procedure will be presented.

Participants

For this particular experiment, participants were chosen from the students of Kennesaw State University. These participants ranged in age from 18 to 34 with most of the students being under 24 and only two students being above the age of 30. The majority of majors were considered suitable for this experiment with the exception of art and science-based majors. Since the experiment was conducted on the Marietta campus of Kennesaw State, the dominant majors were engineering-based majors. This is a STEM university so most of the degrees are based in science, technology, engineering, and math. Also because of the campus, the dominant gender presence in this study is male. The students were asked to participate by means of email, general announcement, and through communication with various professors. Their names and emails were recorded for the sake of contacting the participants as well as recording age and major. The participants had little to no knowledge of what they were going to do during this study, simply that it was a senior thesis and that they had thirty minutes free to participate.

Materials

The materials utilized in this experiment are a laptop, a projector screen, a questionnaire, a short survey, pencils, a notebook, and desks. For the sake of understanding how students learn in a classroom setting, a classroom was reserved by

the honors program to be utilized in this experiment. The laptop was used to create the diagrams, animations, questions, and survey. The notebook was utilized for students to sign in once they arrived at the classroom. The diagrams and animations were then displayed on the screen. Printed copies of the questionnaire and surveys were given to the students along with the IRB consent form that they needed to sign in order to participate. Pencils were provided to the students to answer the questions. The programs utilized on the laptop were Adobe Illustrator, Adobe After Effects, and Pages. Illustrator was used in the creation of both the animations and the diagrams. After Effects was used to animate the diagrams. Pages was used to write the questionnaire and survey.

Procedure

This experiment was designed to be challenging for the participant but to not be a burden in time constraints. Students were to be shown the animations or diagrams depending on which time slot they signed up for and then answer questions based on what they were seeing. The room that was utilized was reserved from two o'clock to four o'clock so the first session began at two and the second began at three. These are the slots that the participants signed up for. The independent variables in this experiment were the animations and diagrams. The dependent variables were the questions given and the time allotted to students to take the test. Between the two test groups, the only thing that changed was whether they watched the animations or viewed the diagrams. The two o'clock group watched the animations while the three o'clock group viewed the diagrams.

It was explained to the participants that they would be answering questions based on what they saw. Participants were asked to sign the consent form then they would be shown either the animations or diagrams depending on what time they participated. There were three of each media and ten questions total. These can be viewed in Appendix B and C. After the questions were over, there would be a short survey to see what their opinions were. The survey questions are located in Appendix D. After they finished answering the questions, they were asked to put down their pencils and wait for everyone else to complete their questions.

To begin the experiment, the computer was set up and tested to make sure that everything would work. Students began arriving shortly before their session. When they walked in the door they were greeted and asked to sign in. The notebook that they signed asked for their name and major. Once they signed in, they were handed a packet that included the IRB consent form, the 10 questions, and the survey. All that was required of them at this point was to find a seat and wait for the experiment to start. When everyone arrived, the students were told exactly what was going to happen during this study. Then they were shown the first animation (or diagram). The students were told to begin answering questions and the animation or diagram remained on the screen for their reference. Upon finishing each set of questions, the participants would put their pencils down and wait. This process was repeated two more times with the viewing and answering questions of the final two diagrams or animations. When the final questions were completed, students were shown the opposite media and asked to answer the survey questions of which they preferred. Students could then return their

pencils and packets while proceeding to leave the classroom. The next section of this paper will discuss what was found from this experiment.

Results

The results of this research found that students learn better from animations than from diagrams. This was proven not only by their test scores, but also by the opinions of the students themselves. From a timing aspect, the diagram group took longer to answer the questions than the animation group. While the animation group finished an average of 71 seconds before the allotted time, the diagram group finished an average of 50 seconds later than the first group. The test scores from the animation group showed that most students received a 50% average and above. The diagram group had the scores more spread out, however, the largest grouping of grades was at 40%. Graph A1 in the appendix shows exactly what scores the students received comparatively. Students went into this study not knowing exactly what was going to happen and therefore some people were rather upset when they found out that most of the questions were difficult. The questions were difficult so that there was no way that the students could have been biased. At this university, it is not a requirement for students to take virology as a class so this information was brand new to most of the participants.

Despite the difficult and unfamiliar quality of the questions, the students performed well over all. It was interesting to find that animations are so heavily preferred. Since the first group did not see the diagrams as was intended, the following numbers are reflective of the data collected from the second group. Of the 20 students who attended the second group, only three students wrote that they preferred the diagrams. Five students mentioned that they would have like to have seen a diagram in place of one of the animations, but keep the other animations for the rest of the questions. These cases were left out of the overall collection of data. Only specifically animation and diagram opinions were recorded in this study. The responses from the first group were primarily preferring the animations, however, since they were not shown the diagrams this data is invalid.

To see if there were any other factors that might play into this result, gender and major were also considered. Taking into consideration that the animation group performed better than the

diagrams group, overall the men had higher averages than the women. From the first group, there were 16 males and nine females. The males had an average of 65% and the females averaged 57%. In the second group there were 15 males and five females. Of those, the males averaged a score of 55% and the females averaged a score of 52%. Graph A2 in the appendix shows the grades for females and males when shown animations and diagrams. Of the engineers, Industrial Engineering Technology majors had the highest average of 70%. The rest of the averages may be viewed in Graph A3. Out of the few who preferred the diagrams, the gender ratio was even. However, most students did prefer the animations over the diagrams. By having Dr. Louten write the questions for this study, it was certain that a student could not have a skewed opinion before participating. The questions were difficult so that the proctor could be sure that the participants were learning a topic that is unfamiliar them.

By engaging in this study, students could have learned valuable information about themselves. Unbeknownst to them, they could be more of a visual learner than they had previously anticipated. The animations allow for a clearer display of these scientific diagrams and as shown by this study, students respond well to them. Few students would have rather had diagrams to answer the questions. In addition, the group who was only shown diagrams to answer questions took more time to answer the questions that they were given. The group of participants that was shown the animations finished well before the allotted time. The following section will summarize the findings of this research.

Summary

When presented the identical information in two different media, students preferred animations over diagrams. There are various reasons why this is true. Although studies from years past have found that animations have little to no positive results with students, times have changed and so has the way that people learn. In this study, there were few students who preferred the diagrams and then some who asked for both at the same time. Most students preferred the animation because of the clarity it provided to each process. One specific comment for the animations was, "I would have preferred the animations because I could actually see the actions of each question, rather than try to visualize the diagram in my mind." This seemed to be a common theme throughout the opinions of the students who preferred to see the animations. The argument from those who were partial to the diagrams was that they clearly explained the process. One student said, "I would have preferred the graphic because the animation takes it step-by-step on a loop but with a diagram I can focus on the step I'm having the most trouble with. If I need to reread something or see something again, it's much easier in a diagram opposed to waiting for the animation to get back to the part I'm having trouble with." While this student provides a valid point, there were only a handful of students who preferred the diagrams. The group who was presented the diagrams took longer to answer the questions given to them. The animation group finished well before time would have been called. Having preference toward the animations could very well have a direct relation with the arguably lackluster means of students gaining and retaining information. Society has progressed so far that information is at a student's fingertips. With so many sources of instant

gratification, it makes sense that the participants preferred the animations over the diagrams when presented new and difficult material. Had the information in this study been on a simpler subject, the results may have been more varied. However, students chose the animations with an overwhelming majority. On top of that their grades were significantly higher. In this age of immediate information, it is beneficial for students to have information presented to them in a similar manner when in the classroom. When a study such as this as well as others before it shows that students perform better when the media shown to them is clear and understandable, the resulting process should be to implement these ideals wherever possible. Students preferred the animations. Students scored better after seeing the animations. Therefore, animations should become more prevalent in classrooms across the nation. The conclusions that can be made from this summary will be presented in the next section.

Conclusion

This study was conducted to determine the relevance of providing animations to teachers to use in the classroom. It was speculated that animations would be a positive experience for students as well as an aid in understanding Virology. The information gained by this experiment will be presented to Dr. Louten and other professors to narrate the importance of various means of imparting knowledge to students particularly in the scientific field. In the past, it was understood that animations were nonessential and almost a hindrance to learning. Now they are welcomed and even preferred. Perhaps this is a generational phenomenon or simply society becoming so used to videos and similar media. Millennials have grown up with the internet and websites like YouTube. They are so used to instant gratification that they expect it in every aspect of their lives. If a video does not start within ten seconds, most move on to the next thing. It seems that society wants information delivered as fast as possible and in the most convenient way possible. To keep students engaged and off of their phones, it is necessary to bring various forms of media into the classroom. Recognizing the need for animations in the classroom will provide opportunity for new jobs for scientific animators. Society has changed so the way that students are being taught should too. If teaching remains the way that it has always been, students have every reason to disengage their brains. They only learn information to be able to spit it out in the form of taking a test and then they forget they ever learned anything. The goals of education are to create humans that go on to be the next generation that changes the world. With or without positive teaching strategies, the next generation will change the world but it may not be for the better. The educational system in the United States needs to make some improvements or be at extreme risk of raising up a generation of people who think that everything should be handed to them and hard work is a phrase they heard one time on television. While this study simply addresses the opinions of whether animations function better than diagrams as an educational tool for the modern student, it also opens the doorway to the possibilities of an educational system that focuses on the needs of the students rather than their test scores.

Annotated Bibliography

Adamczyk, C., Holzer, M., Putz, R., & Fischer, M. R. (2009). Student learning preferences and the impact of a multimedia learning tool in the dissection course at the University of Munich. *Annals of Anatomy-Anatomischer Anzeiger*, *191*(4), 339-348.

This paper discusses how the learning styles of students is not affected by the use of multimedia products. They say that students appreciated the supplemental materials, however, they were not influenced one way or another. This article will be good for my paper because it will allow me to discuss the cons of creating supplemental materials.

Ainsworth, S., Prain, V., & Tytler, R. (2011). Drawing to learn in science. *Science*, 333(6046), 1096-1097.

This article explains how scientists often create images in order to understand processes and ideas. If scientists are known to draw for the sake of comprehension, then why do schools not encourage drawing as well? This article will aid my paper because of its abilities to show the importance of images in the understanding of scientific ideas and processes. I will be able to further develop and comprehend these ideas as the study progresses.

Alessi, S. M., & Trollip, S. R. (2001). *Multimedia for learning: Methods and development*. Boston, MA: Allyn & Bacon, Inc.

This source describes the various ways that people learn and understand differing subject matters. In it, there are the descriptions of theories that describe how they came to understand how multimedia plays a part in the conceptualization of ideas. This source will aid in my understanding of how to go about my study as well as what types of questions I will ask my participants by providing insight from the theories that it discusses.

Alty, J. L., Al-Sharrah, A., & Beacham, N. (2006). When humans form media and media form humans: An experimental study examining the effects different digital media have on the learning outcomes of students who have different learning styles. *Interacting with Computers*, *18*(5), 891-909.

This article explored how the learning styles of students was effected by three different types of teaching. It found that students were more attentive when presented with sound and diagrams together. This will aid my paper in the understanding that professors should include images of all sorts in their lectures for the greater comprehension of their students.

Hegarty, M., Kriz, S., & Cate, C. (2003). The roles of mental animations and external animations in understanding mechanical systems. *Cognition and instruction*, *21*(4), 209-249.

This study is of students' understanding of concepts when presented with static diagrams followed by animations. It shows that while understanding increased, there is not enough evidence to suggest that the animations are more beneficial. This will aid in the cons section of my paper, but also provide awareness of the beginnings of the helpful nature of animations in the early two thousands.

Henriksen, B., & Neppl, A. (2014). Full-motion videos: Bringing abstract chemical concepts to life in the classroom. *Currents in Pharmacy Teaching and Learning*, *6*(3), 380-385.

This article discusses how helpful animations are due to the inability of 2D images and diagrams to provide sufficient information to students. Not only did students enjoy the animations, but their scores also improved from viewing them. The article focuses on testing students on chemical concepts which will be beneficial because of its ability to coincide with my paper's topic of virology.

Höffler, T. N., Prechtl, H., & Nerdel, C. (2010). The influence of visual cognitive style

when learning from instructional animations and static pictures. *Learning and Individual Differences*, *20*(5), 479-483.

This study was conducted on the basis of two different types of learners being able to understand information through animations and pictures. It found that the animations did not help or hinder the learners, but the "highly developed visualizers" learned better from creating their own animations in their minds. This article will aid in my discussion of the cons of animations versus still images by offering insight into the visual learner's mind and way of understanding concepts.

Johnson, A. M., Ozogul, G., & Reisslein, M. (2015). Supporting multimedia learning with visual signalling and animated pedagogical agent: Moderating effects of prior knowledge. *Journal of Computer Assisted Learning*, *31*(2), 97-115.

This study was conducted to see how students learn when they have been previously exposed to information versus when they have no prior knowledge. They found that students with prior knowledge of the information learned less with the animations than students beginning with less prior knowledge. They have even determined that if a student already has knowledge then the animation is redundant and does not benefit the student at all. Therefore animations should only be used on students who have little prior knowledge of the information that is being conveyed. This information will aid in my paper because of the pros and cons that it presents of showing students new information through animations.

Mayer, R. E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of educational psychology*, *93*(1), 187.

This study was conducted to discover the value of multimedia usage in classrooms. The people conducting the research wanted to see if the addition of on-screen text or interesting words during the video would increase the student's abilities to comprehend what they are learning. This study was intended to be valuable for

students who learn either visually or auditory. They found that the extra text caused students to do worse than those who viewed the animation without the extra wording. This study will aid in my research by providing results from a similar experiment that I may compare my findings to.

Morrison, J. B., Tversky, B., & Betrancourt, M. (2000). Animation: Does it facilitate learning. *AAAI spring symposium on smart graphics*, 53-59.
This article discusses graphics and animations and their uses in education. It goes into depth describing both along with their pros and cons. The article does not find animation to be useful over graphics and therefore will be intriguing in the cons section of my paper. It will be useful to understand this article's findings when comparing it to the more recent studies on the same topic. Society has changed in the past sixteen years so it will be interesting to see how much that change has affected the learning style of students.

Niknejad, S., & Rahbar, B. (2015). Enhancing EFL learners' reading comprehension ability through multimedia-based visualization. *Journal of Applied Linguistics and Language Research*, *2*(6), 119-127.
This study was completed to see if English as a Foreign Language students could understand what they were being taught better from still images or animations. It finds that the animations produced a better effect on the students. This article will be good to have in my paper to discuss not only how society has changed and become more understanding in the more recent years of animations, but also how our minds have adapted to understanding animations.

Paris, P. G. (2004). E-Learning: A study on secondary students' attitudes towards online web assisted learning. *International Education Journal*, *5*(1), 98-112.
This article discusses a study done to see how students performed when presented with "paper assisted learning" versus simply learning from an online course. It found

that students preferred the online learning over the former. This research will aid my paper in that it justifies that students are open to learning from various forms of multimedia.

Perry, M. J. M. (2013). Effects of visual media on achievement and attitude in a secondary biology classroom. (Master's thesis). Retrieved from https://www.ohio.edu/education/academic-programs/upload/Michelle-Perry-Masters-Research-Paper-copy.pdf

This study was conducted in a biology classroom to discover if animations in addition to traditional teaching would improve students' ability to learn as well as general mood. It found that there was not a substantial difference between the test group and the control group. The only benefit found was that students enjoyed the videos. This knowledge will aid my paper in the consideration of the emotional benefits provided by viewing animations as well as the educational.

Ploetzner, R., & Lowe, R. (2012). A systematic characterisation of expository animations. *Computers in Human Behavior*, *28*(3), 781-794.

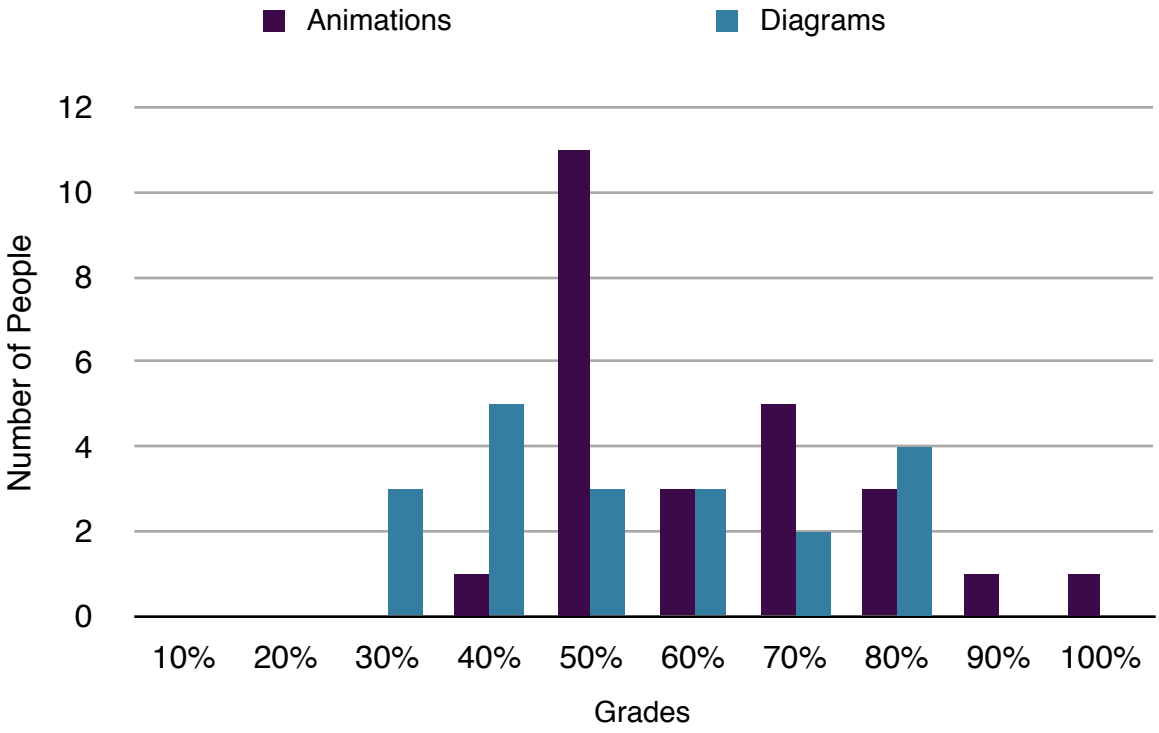
This article discusses how animations have been used in education but there is a lack of understanding what it is about animations that aids in student's learning. It found that even though learning from animations is still in its early stages, it is likely that this style of learning will become a prominent way of presenting information. This will aid my paper by allowing me to further show the importance of animation in the field of education.

Zahra, S. B. (2016). Effect of visual 3D animation in education. *European Journal of Computer Science and Information Technology*, *4*(1), 1-9.

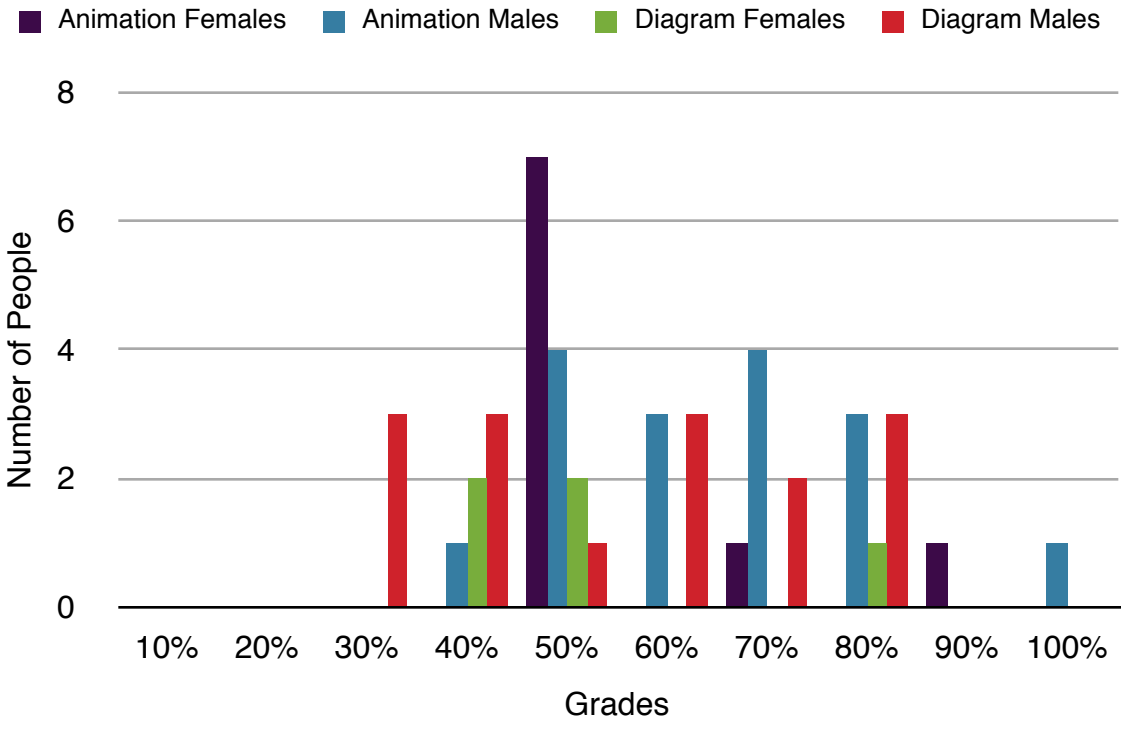
This study was conducted to test the benefits of animations in the classroom. It found that students responded well to the animations. This will be beneficial to my paper due to the positive outcome of the study on both the emotional and educational

responses of the students. It will add on to the favorable view of animations in education and will do good to show that more recent studies approve of animation in the classroom.

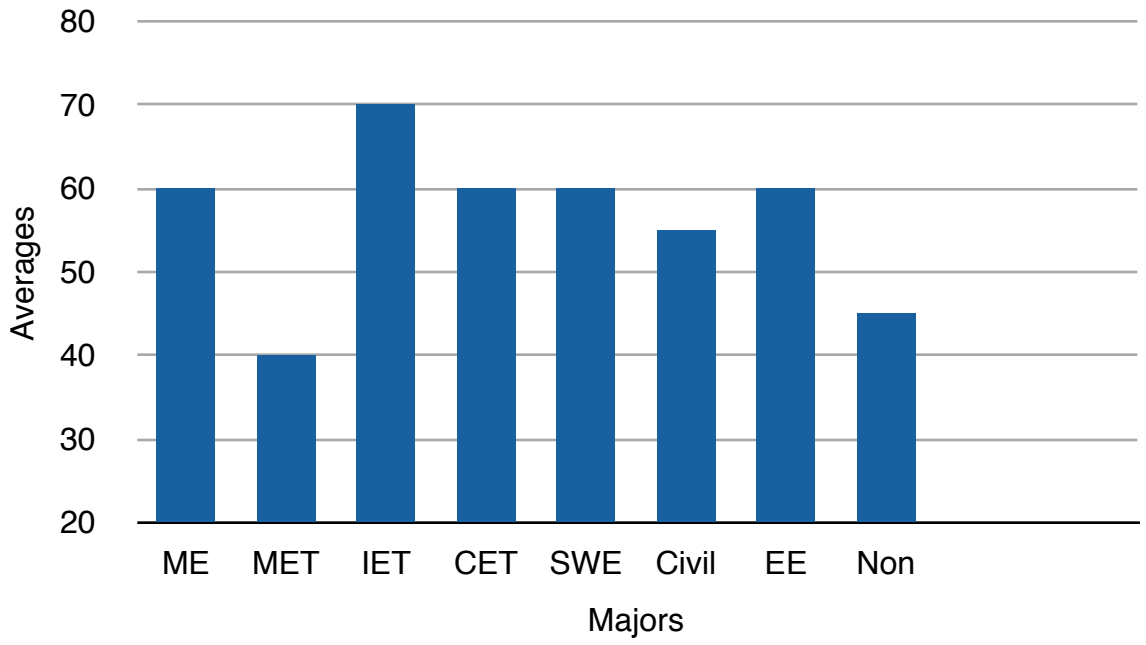
Appendix A



Graph A1: Grades of Students in the Groups Shown Animations vs Shown Diagrams



Graph A2: Grades of Females vs Males When Shown Animations and Diagrams



Graph A3: Averages of Majors in the Study

Key:

ME - Mechanical Engineering

MET - Mechanical Engineering Technology

IET - Industrial Engineering Technology

CET - Computer Engineering Technology

SWE - Software Engineering

Civil - Civil Engineering

EE - Electrical Engineering

Non - Any major that was not an engineering major

Appendix B

Diagrams and Questions Presented to Students

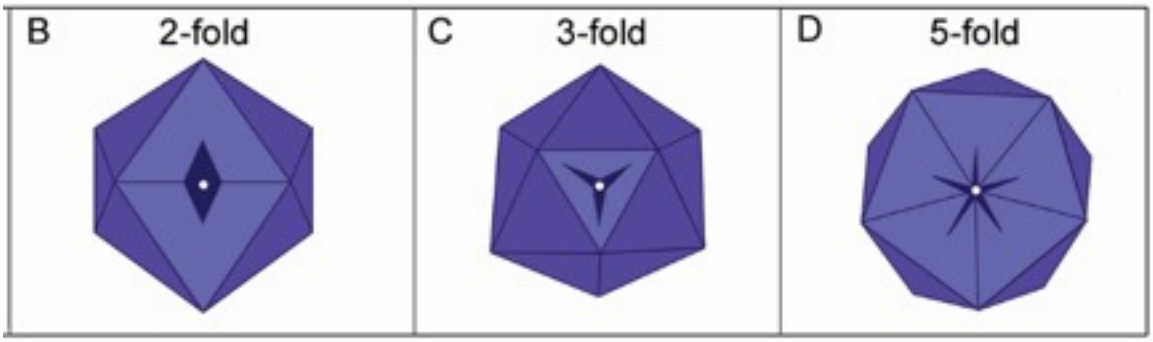


Image B1: Icosahedron Axes of Symmetry

Icosahedron Axes of Symmetry. B) The 2-fold axis of symmetry occurs when the axis is placed through the center of an edge. The 3-fold axis occurs when the axis is placed in the center of a face (C), and the 5-fold axis passes through a vertex of the icosahedron (D).

Questions:

1. An icosahedron possesses _____ axes of symmetry.
   a) 2-4-5
   *b) 2-3-5
   c) 2-3-4
   d) 1-3-5
   e) 1-3-4

2. An icosahedral capsid is composed of _____ sides, each in the shape of a(n) _____.
   a) 12; pentagon
   b) 20; right triangle
   c) 12; right triangle
   d) 12; equilateral triangle
   *e) 20; equilateral triangle

3. How many 3-fold axes of symmetry are found in an icosahedron?
   a) 1
   b) 3
   *c) 10
   d) 12
   e) 20

4. In rotating an icosahedron on its 3-fold axis of symmetry, an identical shape is encountered every _____ degrees.
   a) 15
   b) 30
   c) 50
   *d) 120
   e) 180

* Dennotes the correct answer. These were not present when given to students.

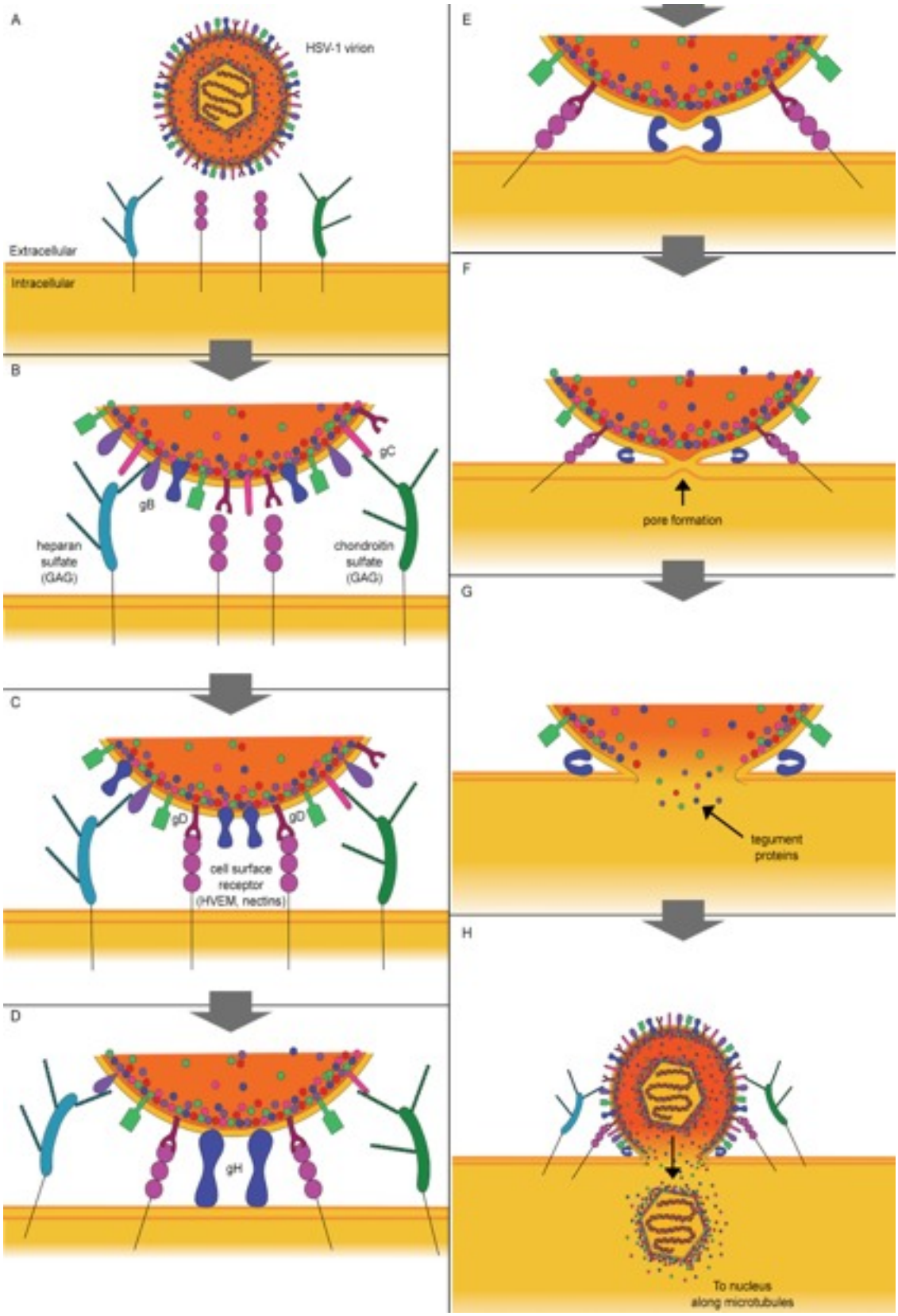


Image B2: Herpesvirus Entry

Herpesvirus entry. A) Herpesviruses possess several envelope glycoproteins that facilitate the process of entry into the cell. B) For HSV-1, gB and gC bind to glycosaminoglycans (GAGs), including heparan sulfate and chondroitin sulfate, on the cell surface. This brings gD into close contact with a specific cell surface receptor, such as HVEM, nectin-1, or 3-OS heparan sulfate (C). Binding of gD to the receptor allows the association of gD with gB, gH, and gL. All 4 proteins are required for fusion, but gH possesses a possible fusion peptide (D). The gH protein undergoes a conformational change, bringing the virion envelope and plasma membrane closer together (E, F) until they fuse together, creating a pore (G). The capsid is released into the cytoplasm, escorted by tegument proteins that assist in the binding of the capsid to the microtubule transport machinery that will transport the capsid to the nuclear envelope.

Questions:

1. Which of the following proteins likely facilitates fusion of the viral envelope with the plasma membrane?
   a) gB
   b) gD
   *c) gH
   d) gL

2. Which of the following proteins does NOT participate in HSV-1 attachment to the cell surface?
   *a) gA
   b) gB
   c) gC
   d) gD

3. Tegument proteins play the largest role in which of the following stages?
   a) Attachment of the virus to the cell surface
   b) Fusion of the viral envelope with the cell membrane
   *c) Escorting the released capsid to the nucleus
   d) Tegument proteins function at all of the above stages

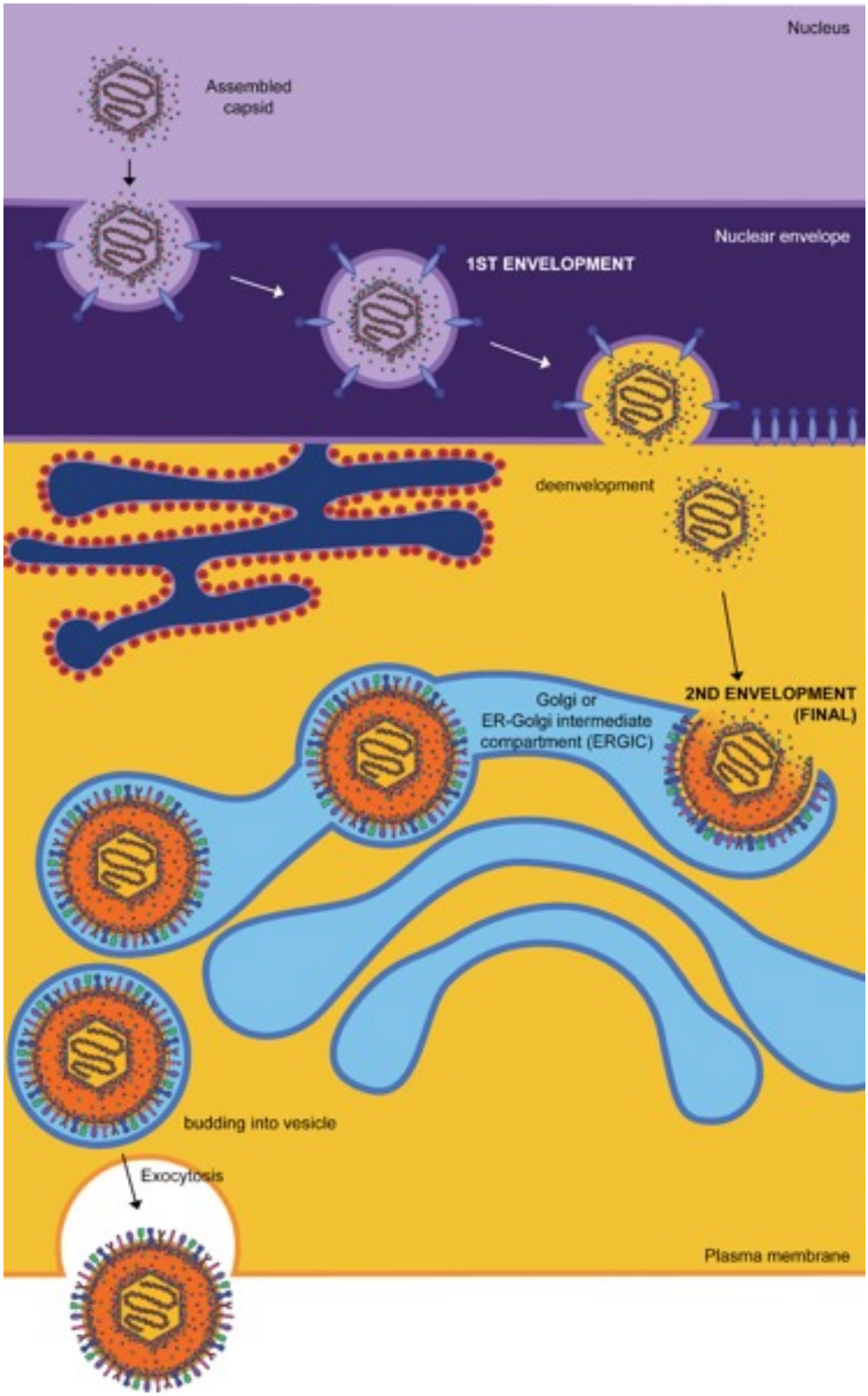


Image B3: Double Envelopment, Assembly, and Release

Double envelopment, assembly, and release. To pass from the nucleus into the cytoplasm, the nucleocapsid must traverse the double membrane of the nuclear envelope. To do so, it buds through the inner nuclear membrane, acquiring an envelope from it. Now in the intermembrane space, the temporary envelope fuses with the second nuclear membrane to release the capsid into the cytosol. Viral proteins assemble on one of the membrane organelles within the cell, from where the nucleocapsid acquires its final envelope. The virion is released via exocytosis.

Questions:

1. True or False: the final envelope membrane acquired by the herpesvirus is derived from the nuclear envelope.
   a) True
   *b) False

2. The proteins that are located on the final envelope membrane become embedded into the membrane:
   a) In the nucleus
   b) At the nuclear envelope
   *c) At the Golgi or ER-intermediate compartment
   d) While in a vesicle
   e) At the plasma membrane

3. Why does the assembled capsid need to undergo the 1st envelopment step?
   *a) To escape from the nucleus
   b) To escape from the cell
   c) To have proteins embedded onto the virus
   d) To prepare for the 2nd envelopment step

Appendix C

Animation Screen Shots

Image C1: 2 Fold Axis of Rotation

Image C2: 3 Fold Axis of Rotation

Image C3: 5 Fold Axis of Rotation

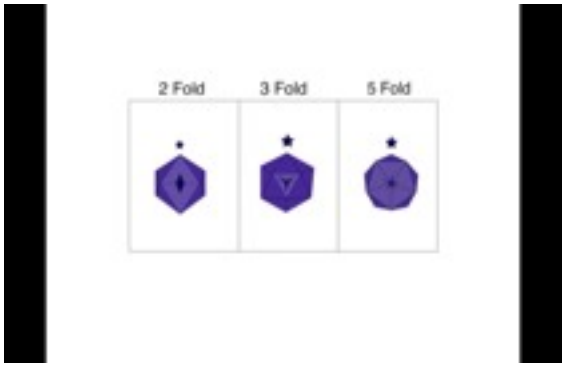


Image C4: Axes of Rotation

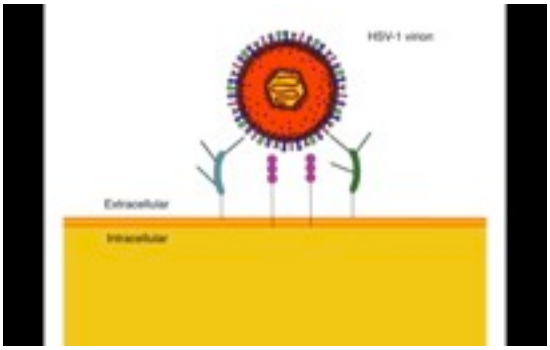


Image C5: Herpesvirus Entry A

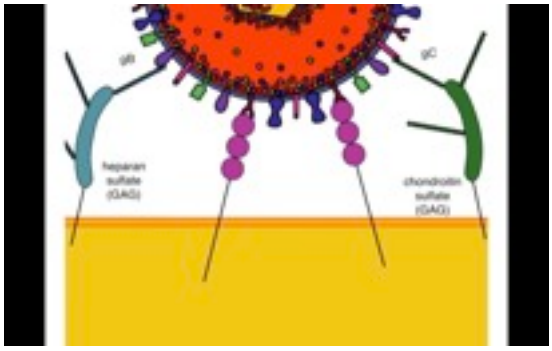


Image C6: Herpesvirus Entry C

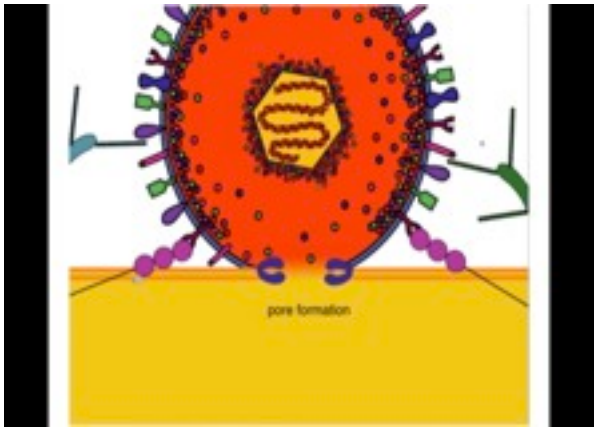


Image C7: Herpesvirus Entry G

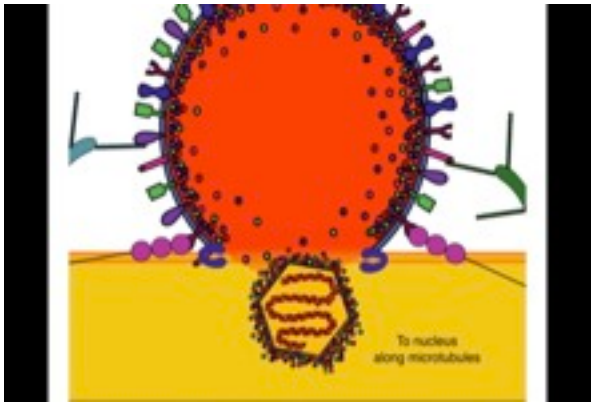


Image C8: Herpesvirus Entry H

Image C9: 1st Envelopment

Image C10: De-Envelopment

Image C11: 2nd Envelopment (Final)

Image C12: Budding into Vesicle

Appendix D

Post-Test Survey Questions

1. How did the graphic (animation) help with recalling information to answer the questions?

2. Would you have preferred to have seen the graphic or the animation? Why?