THE IMPACT OF TECHNOLOGY ON ENGAGEMENT AND CONTENT MASTERY IN HIGH SCHOOL BIOLOGY

by

Jennifer Marie Livesay

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2022

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

Tables Page

LIST OF FIGURES

Figures Page

ABSTRACT

The use of technology-mediated versus traditional paper-based delivery methods as a means of increasing student mastery and engagement was studied in the areas of notetaking and simulations. Data collection instruments included pre- and post-content tests with confidence response measures as well as both Likert-item and open-ended response surveys. Data was analyzed using both quantitative and qualitative methods. The results indicate that technology leads to increased levels of engagement and mastery when utilized as a way to model scientific processes, but a decrease of mastery and engagement when used as the medium for notetaking.

INTRODUCTION AND BACKGROUND

Context of the Study

I have been teaching biology at Permian High School in Odessa, Texas for five years. According to the Ector County website, the district serves approximately 34,000 students, with nearly 4,000 students at Permian High School each year across four grade levels (Ector County Independent School District, n.d.). The district overall has 55% of students identified as economically disadvantaged, and 21% with limited English proficiency. Sixty percent of the students in my district are also at risk of dropping out prior to graduation (Texas Tribune, 2019). I have recently switched from high at-risk students to honors this school year. These students are significantly lower than the district average in their inclusion of economically disadvantaged at only 36%, and just 5% are identified as having limited English proficiency. However, there is a consistent thread between at-risk, ELL, and honors students and that is engagement. The ability for students to become interested in their work and interact with their peers on content mastery tasks is critical for student success on their state end-of-course exams.

My first year of teaching at Permian was the 2018/2019 academic year. That year, I conducted instruction in traditional formats using PowerPoint presentations for guided notes, collaborative activities using paper-based manipulatives and models, as well as hands-on laboratory activities. During that time, I observed that student engagement seemed inconsistent. During some activities, nearly all my students were attentive and working with their peers and problem solving, but with others they would not attempt reading the objectives and instructions and were easily off topic. These off-topic students

would engage in distracting activities such as small-talk, doodling, or be interacting with personal devices. The following year I had begun to use new activities I had acquired from colleagues, and altered others to mirror the more successful lessons I had used in the past more closely in an effort to increase engagement. These activities and modifications included manipulatives, station problem-solving, and model building using crafting materials.

In the Spring of 2020, COVID-19 struck and drastically changed how I approached learning and engagement. The spring semester of 2020 was trial and error for the district, as we navigated how to conduct distance education. According to a district-wide survey conducted that semester via Panorama Education (2020), approximately 75% of students reported not feeling engaged in the virtual lessons. By the Fall of 2020, quarantine and distance learning were still in place. I continued to find and incorporate different platforms to address the general apathy the students reported, and that I had observed, the previous semester.

At first, I found any sort of engagement difficult to evaluate. Students were not actually required to attend meetings to be counted present. They could work through the material on their own and still earn attendance credit. Students also were not required to have cameras on for security reasons, other than for exams. Students were hesitant to speak out and I often did not know if they were present or just logged in. My solution to this was to incorporate the interactive presentation application Nearpod. Nearpod requires students to respond to questions and engage in activities throughout the lesson, and was one way I was able to get some measure of engagement from the students. I was also able to provide immediate feedback and allow students to correct their responses in real time.

By using this approach, virtual student scores increased on the first four unit exams from an average of 78% to 85% and were higher than the district average by four to ten percentage points. While my students did see a year-over-year decline, it was a consistently smaller decline than that experienced across the district. Missing from this setting was an ability to develop and evaluate laboratory skills and, by extension, many inquiry and processing skills. While some simulations were available online, they were often unreliable and unclear to the students. The lack of efficient laboratory tools and simulations has led to a gap in their data analysis and collection skills, which are imperative to science education.

The superintendent has presented a plan for how education will look in the district moving forward. In this plan, there will be an increased incorporation of technology for students in and out of the classroom, and virtual learning continues to be an option for students meeting specific criteria. From my experience with virtual education throughout the Covid-19 pandemic, I know it is possible to successfully incorporate digital learning, however there are still several identified areas of improvement, most notably in laboratory skills and data analysis. Students returned full time to the classroom in the Fall semester of 2021, with the superintendent's plan still not clear. However, we were told to incorporate digital learning as much as possible and move towards becoming paperless. The purpose of this study was to determine where technology could prove to be superior to traditional methods of instruction, and where traditional methods would still be best for student engagement and content mastery.

Focus Statement/ Question

My focus question was, “How is student engagement and content mastery affected by the use of technology in the science classroom?”

My sub-questions included the following:

1. Does the use of digital simulations as a laboratory activity increase students’ understanding of the laboratory learning objectives when compared to paper based manipulative simulations?
2. Will student engagement and mastery of learning standards increase with a mixture of digital response systems and paper notetaking during the introductory phases of units compared to fully digital notes?
3. Do students self-report higher satisfaction, engagement, and learning with the use of digital notetaking and simulations compared to traditional paper-based delivery?

CONCEPTUAL FRAMEWORK

Engagement and Teaching Practices

Over the last century, increased attention and study has been focused on improving student learning by analyzing how well students are engaged. Engagement can be described as a student's active participation and commitment to the process of learning (Halvorson & Graham, 2019). When looking at specific aspects of student engagement as described by various models, there are a few common characteristics that emerge. The first is that a truly engaged student finds personal value in what they are learning. They can see the significance of their learning to self-improvement, improvement to society, or their future goal attainment. Engaged students are also persistent with tasks even when faced with difficulty. The student maintains high expectations for their performance, even if the teacher expectations are lower. And lastly, students often dedicate their personal time to further engaging with the material or field of study for personal enjoyment and fulfillment. This can come in the form of things like personal research or engagement with related extracurricular activities (Grabau & Ma, 2017; Schlechty, 2011).

High engagement has been shown to be closely associated with high achievement in several standardized measures (Tamim et al., 2011). Therefore, it is critical that educators understand how teaching practices can lead to higher engagement. Research consistently shows that modelling and hands-on learning are two key practices that lead to increased engagement and achievement (Bryce et al., 2016; Grabau & Ma, 2017; Louca, 2011). These practices have been incorporated into current frameworks of

science education including inquiry-based learning, the Next Generation Science Standards (NGSS), and the 5-E model.

Engagement and Technology

A tool that is increasingly used to facilitate higher engagement in the classroom is technology. Technology refers to electronic items, such as laptops and tablets, and the applications they run, such as word processing and slideshow applications. By 2016, 89% of students reported regular usage of technology in the classroom (Gallup Inc, 2019). The literature on whether technology can achieve its goal of increasing engagement and achievement is mixed. A study conducted by the Organization for Economic Cooperation and Development (OECD) across several countries found no significant increase of engagement or achievement when information and communication technologies were used in school (Spiezia, 2010). In contrast, a meta-analysis of over 80,000 studies did indicate that technology use in science was likely to have a small but positive impact on achievement *(EF=0.23)*, particularly when incorporating modelling and simulations *(EF=0.35)* (Hattie, 2017).

T3 Model and Applications of Educational Technology

Given the broad scope of the OECD study and the meta-analysis, it is valuable to look at more focused work to determine where technology use would prove to be beneficial, neutral, or negative in its impact on engagement and achievement. To better analyze technology use in education, Magana (2019) developed a three-tiered, or T3, framework for technology innovation and usage. As you move up through the tiers or domains, the effect sizes of engagement and achievement generally increases.

Domain One: Translational

The first tier is described by Magana (2019) as "translational" use of technology. This is where classroom strategies and tasks are simply turned into a digital form. This includes items like digital polling, quizzes, and notes, which are the most common usage of technology in the classroom. The benefits to the teacher are high in this level in terms of increased efficiency of assessment and timely feedback (Magana, 2019).

The benefits to the students in the first tier vary according to the task being digitized. Virtual polling and anonymous digital response systems have shown to increase student engagement and achievement, as well as be a more satisfactory experience for the student (Blood, 2008; Hakami, 2020; Poirer, 2007; Rila, 2019). However, when note-taking is conducted on a computer, there is a significant drop in student engagement during class, and later recall on assessments. The negative impact on engagement and achievement is reduced when tablets and digital writers, that more closely resemble paper and pen, were utilized (Morehead, 2019).

Domain Two: Transformational

The second tier of the T3 framework includes activities designed to increase production and contribution. In this tier, technology is used to facilitate collaboration between students, increase student self-generated feedback, and generally allows students to design and engage instead of just consume (Magana, 2017). Of particular application to science in the 2nd tier would be the ability to engage in virtual simulations of modelling systems. As discussed above, modelling and simulations have been shown to increase engagement and achievement (Hattie, 2017). These gains increase when using

technology, particularly in the areas of genetics (E=0.87) and cell theory (E=1.54) (Rutten, 2012).

Domain Three: Transcendent

The third and highest level is where students identify and investigate real problems and work towards their own solutions. For science education, this would mean taking the laboratory experience to a higher level. Instead of engaging in simulations with pre-determined parameters and steps, the student would be freer to develop and design the experience using the digital tools to solve a real problem. In addition to gains of content mastery, students reported a higher level of engagement and enjoyment, particularly when virtual labs were used in conjunction with actual hands-on laboratory activities (Špernjak & Šorgo, 2018). The third domain of the T3 model coincides with the indicators of a truly engaged student earlier identified by Grabau and Ma (2017) where the student was able to take ownership of their educational experience and increase their understanding of the value of the task.

METHODOLOGY

Demographics

My Action Research (AR) study followed the effects of digital based simulations and notetaking on student concept mastery and engagement in the science classroom. I wanted to determine if paper or digital simulations showed higher increases in content mastery and engagement, as well as digital versus paper notetaking. In addition, I wanted to determine if the treatment resulted in student-reported higher satisfaction, engagement, and learning with digital or traditional instruction. The district overall has 55% of students identified as economically disadvantaged, and 21% with limited English proficiency. Sixty percent of the students in my district are also at risk of dropping out prior to graduation (Texas Tribune, 2019). For the honors biology classes used in this study, the demographics are a bit skewed from the general trends of the district. According to the district data management system Ascender, of the 197 students enrolled in honors classes and used for this study, 36% are identified as economically disadvantaged (n=71) and 5% of the students have limited English proficiency (n=10). In addition, 37% of the students are identified as gifted and talented (n=73). To ensure consistency, all class periods took the pretest assessment, and two were selected to be part of the experiment based on statistical similarity utilizing a t-test analysis.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

Treatment

In my mixed methods research study, the unit chosen for this study was the seventh unit of freshman biology, i.e., Evolution. At the beginning of the evolution unit, students were given the Mechanisms of Evolution Pretest (Appendix B). The class scores were analyzed using a t-test and the two class periods with the most statistically similar results were chosen to be part of the experiment based on the similar pretest scores. The two classes were assigned as either control or experimental at random. All students were then given the notes and lesson on the mechanisms of evolution. The control group followed the lesson with a paper-based manipulative scenario that illustrated how a population shifts based on introduced variables. The experimental group was given a computer-based PhET simulation assignment that allowed them to manipulate variables digitally and to show population shifts over time. Students were then given the Mechanisms of Evolution Posttest (Appendix B) to obtain data to calculate mastery gains and the Likert Survey of Computer-Based Simulation Learning (Appendix C) to determine engagement. In addition to raw test scores, confidence questions were embedded for each question that asked students to rank their confidence in their correct answer on a 1-3 scale. This allowed me to gain more information on their perceptions of their own mastery of the content and allowed me to determine when correct answers were given on the multiple choice by luck, rather than knowledge.

For the second part of the study, evaluating the impact of digital notetaking on mastery and engagement, an introductory lesson on the evidence of evolution was used. The same pretest and group assignment process was utilized as described above. Both groups had the lesson provided through the digital platform Nearpod. The Nearpod app allows for embedded media within a standard digital slideshow. The control group

completed their notes in a standard paper template. Students in the experimental group were instructed to complete their notes through the classroom management application Schoology. Students were then given the Evidence of Evolution Posttest (Appendix D) to determine mastery gains and the Likert Survey of Computer-Based Notetaking (Appendix E) to determine student attitudes on the experience. At the end of the unit, all groups participating in the study were given the option to complete the Open-ended Survey of Student Engagement and Accessibility (Appendix F) to allow students the ability to provide feedback and context that may not have been allowed for in the two Likert surveys.

Data Collection and Analysis Strategies

To determine how the students were impacted using technology, several instruments and data analysis methods were utilized. To gain a better understanding of the overall experience from the students' perspective, a mixed methods approach was implemented. This consisted of pretest/posttest quantitative analysis, Likert surveys, and open-response surveys.

Data Collection Methods

The Mechanisms of Evolution Pretest is a ten-question assessment that includes multiple choice single-answer responses and a multiple choice multiple-answer response (Appendix B). In education, it is common to use quantitative research design and standardized assessments as a means of evaluating instructional effectiveness in a value-added model (Vogt, 2011). In this case, I measured the effectiveness of a digital simulation compared to a paper-based simulation. I chose a two-group pretest and

posttest design. This design is used when the changes between groups are dependent on a variable, in this case the type of simulation (Allen, 2017). The pretest provided a measure prior to administering the treatment that served as a baseline comparison for the control and experimental groups. The administration of the pretest also allowed me to conduct analysis on the groups to determine if they were statistically similar or if groups needed to be rearranged to ensure similarity (Mertler, 2020). To determine the structure of the standardized pretest, I wanted to mimic the means of assessment used by the state. Student mastery is assessed through the State of Texas Assessment of Academic Readiness, or STAAR, end of course exam (TEA, 2020). This test is multiple-choice with four answer options for each question. I have utilized a similar format for assessing mastery and growth for this experiment with the Mechanisms of Evolution and the Evidence of evolution pretests.

The posttest was given after the treatment to the control and experimental groups. The posttest was identical to the pretest in the questions asked. With a control group and an experimental group that were statistically similar on the pretest, I was able to conduct analysis on the posttest to determine gains between the groups. T-test analysis was then conducted between the groups to determine if there was statistical difference due to treatment (Mertler, 2020).

Students completed the Likert Survey of Student Perceptions of Computer-based Simulations which gave me contextual information on the usage of computer-based simulations compared to standard paper-based methods (Appendix C). All options were presented using a 5-point scale continuum, with a neutral option provided. While the inclusion of the neutral option is debatable (Mertler, 2020), I have included it here to

allow for accuracy of those that truly had no opinion. This survey was only given to the experimental groups but allowed me to see how students perceived the usage of computer simulations on their mastery. Students were given paper-based activities throughout the year, so they had prior knowledge and experiences to draw from for comparison. This survey provided me with contextual data on how they viewed their mastery compared to the actual results of the pre-posttest analysis. I was also able to determine how they perceived the value of this experience to their education. The data was analyzed by frequency and graphed, as other means of data analysis are not available with ordinal responses (Bowen & Bartley, 2014).

The Evidence of Evolution Pretest is a twelve-question assessment that was given to students prior to the lessons on the evidence of evolution (Appendix D). Like the pretest for mechanisms of evolution, I utilized the same multiple-choice format modelled after the STAAR test. This provided me with the baseline of data that was used to create statistically similar control and experimental groups (Mertler, 2020).

The students were given an assessment that was identical to the pretest after the treatment was administered. In this case, the treatment was the mode of notetaking with the control group taking their notes in the traditional paper-based method and the experimental group taking their notes digitally through Google Slides. The post-test results were analyzed using a t-test to determine if there was any statistical difference in the gains of the two groups (Mertler, 2020).

Students completed the Likert Survey of Student Perceptions of Computer-based Notetaking on their perceptions of the accessibility and ease of notetaking online versus taking their notes on paper (Appendix E). Only the students in the experimental groups

completed the survey. The students were able to complete their notes on paper throughout the year and used that as their comparison. The survey gave me insight into how students viewed their ability to utilize the notes in working towards content mastery. The data was graphed, and the frequency analyzed to determine trends (Bowen & Bartley, 2014).

Students that were in the experimental groups were given the option to complete an open response survey that included six short questions regarding their views on the experience and provide any feedback (Appendix F). While the Likert survey allowed me to get specific data on their attitudes, the open-response survey allowed me to get qualitative data that may have been omitted with the Likert attitude surveys and allowed the students to elaborate on their views and responses from the other study instruments. (Given, 2012). The data was analyzed utilizing a word-cloud application to look for frequencies of words for each given response. From there, similar terms and concepts were used for emergent theme analysis (Given, 2012). By utilizing these methods, I was able to gain multiple data collection points in order to address my focus questions (table 1).

Table 1. Data Triangulation Matrix.

	Focus Questions		
Data Collection Instruments	Does the use of digital simulations increase students' understanding compared to a paper-based manipulative simulation in science?	Will student mastery increase with a mixture of digital response systems and paper notetaking during the introductory phases of science units compared to fully digital notes?	Do the students report a higher level of engagement, satisfaction, and learning with the integration of technology into the science curriculum?
Mechanisms of Evolution Pretest	X		
Mechanisms of Evolution Posttest	X		
Response Confidence Scale- Mechanisms	X		
Likert Survey of Computer-Based Simulation Learning	X		X
Evidence of Evolution Pretest		X	
Evidence of Evolution Posttest		X	
Response Confidence Scale- Evidence		X	
Likert Survey of Computer-Based Notetaking		X	X
Open-ended Survey of Student Engagement and Accessibility			X

Analysis Strategies

The Open-Ended Survey of Student Engagement and Accessibility items was reviewed to determine specific word frequency in responses. Related words and responses were grouped together and then categorized to analyze emergent themes

(Given, 2012). This enabled me to identify common trends in responses and the responses were compared to the quantitative data collected.

To assess whether the experimental and control groups were similar on the pretest performance, I completed a t-test. I needed to ensure that both groups were not statistically different at the start. A post-treatment t-test was also conducted to determine if there was statistical variance between the control and treatment group and to determine effect size. For each class period, I also analyzed student confidence ratings between the pre and posttest.

For the Likert-type items, I chose a 1-5 scale, with three being neutral. I determined the median value for each question to determine whether the data generally fell with agreement, disagreement, or neutral. Further statistical analysis was not conducted as the data collected was ordinal in nature, and, therefore, cannot be subject to statistical tests like a t-test, ANOVA, nor could a mean be calculated (Bowen & Bartley, 2014).

DATA ANALYSIS

Digital Notetaking

Pretest and Posttest Analysis

The first set of data that was analyzed was the pre and posttest data of student notetaking methods regarding the evidence of evolution. On the pretest, the average score for the experimental group was 45.8%, compared to the average score for the control which was 45.4%. The pretest t-test analysis between the control and experimental groups showed a p-value of 0.93. There was a significant drop on the posttest to a p-value of 0.12, with the average score for the control group increasing to 69.1% and the experimental group score increasing to a 62.7% (Table 2). The confidence responses between the two groups also saw a significant difference, as the control group saw a 76% reduction of responses of "I guessed/not very confident" (n=98 *to* n=24) while the experimental group only saw a 53% reduction of "I guessed/not very confident" responses (n=118 *to* n=56) (Figure 1).

Table 2. Evidence of Evolution Pretest and Posttest Scores.

	Pretest	Posttest
8th period (experimental)	45.8%	62.7%
7th period (control)	45.5%	69.1%

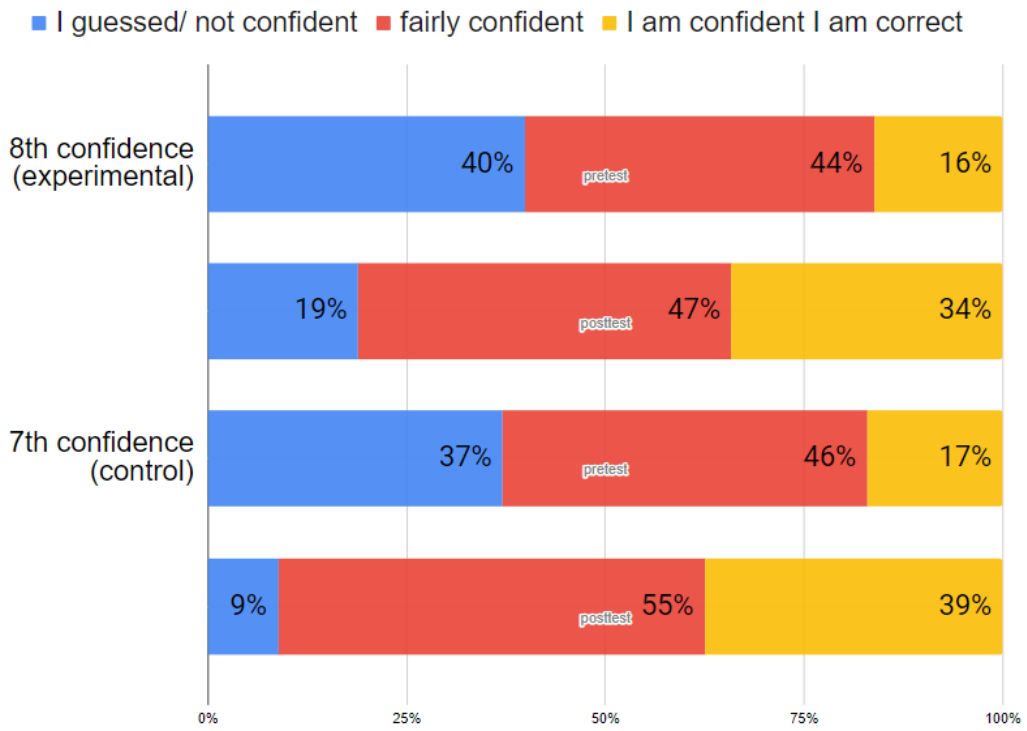


Figure 1. Confidence of evidence of Evolution Pretest/Posttest student responses.

Likert Survey

The student Likert survey of Digital Notetaking responses regarding their perceptions of digital notetaking were then analyzed. Student responses were analyzed collectively as agree, neutral, or disagree. Questions were phrased indicating positive response to digital notetaking, meaning that a disagree response reflected a negative attitude towards digital notetaking. Student responses skewed towards disagree, as the number of responses that disagreed had a range of n=14 to n=22. Response of disagree exceeded the combined total number of responses of "neutral" (range of n=7 to n=10) and "somewhat agree" and "strongly agree" (range of n=4 to n=9) in all survey items

except for organization. (Table 3). This indicates a strong negative perception of digital notetaking.

Table 3. Responses for Likert Survey of Digital Notetaking.

	1. It is easier to take notes digitally than on paper.	2. I gained a higher mastery of content taking notes digitally than on paper.	3. Digital notes are easier to access when needed for studying and assignment completion.	4. Digital notes are easier to personalize than paper notes.	5. Digital notes are easier to organize. (Example: by topic, unit, or level of understanding.)	6. I feel satisfied with the experience towards my learning.
strongly or somewhat disagree	18	22	19	20	14	17
neutral	7	7	8	7	10	7
strongly or somewhat agree	8	4	6	6	9	9

Digital Simulations

Pretest and Posttest Analysis

The next set of data that was analyzed was the Mechanisms of Evolution Pretest and Posttest results regarding the use of digital simulations. On the pretest, the average score for the control group (n=35) was a 47.4%. The average score for the experimental group (n=30) was a 48.0%. The pretest t-test analysis between the control and experimental groups showed a p-value of 0.90. There was a significant drop in the p-

value on the posttest to a 0.25, with the average score for the control group increasing to 68.9% and the experimental group score increasing to a 63.2%. The control group responses saw a reduction in frequency that answered "I guessed/not very confident" by 35%, whereas the frequency of responses of "I guessed/not very confident" reduced by 41% in the experimental group, showing an increased confidence in the experimental group.

Table 4. Mechanisms of Evolution Pretest and Posttest scores.

	Pretest	Posttest
4th period (experimental)	48.0%	68.9%
8th period (control)	47.4%	63.2%

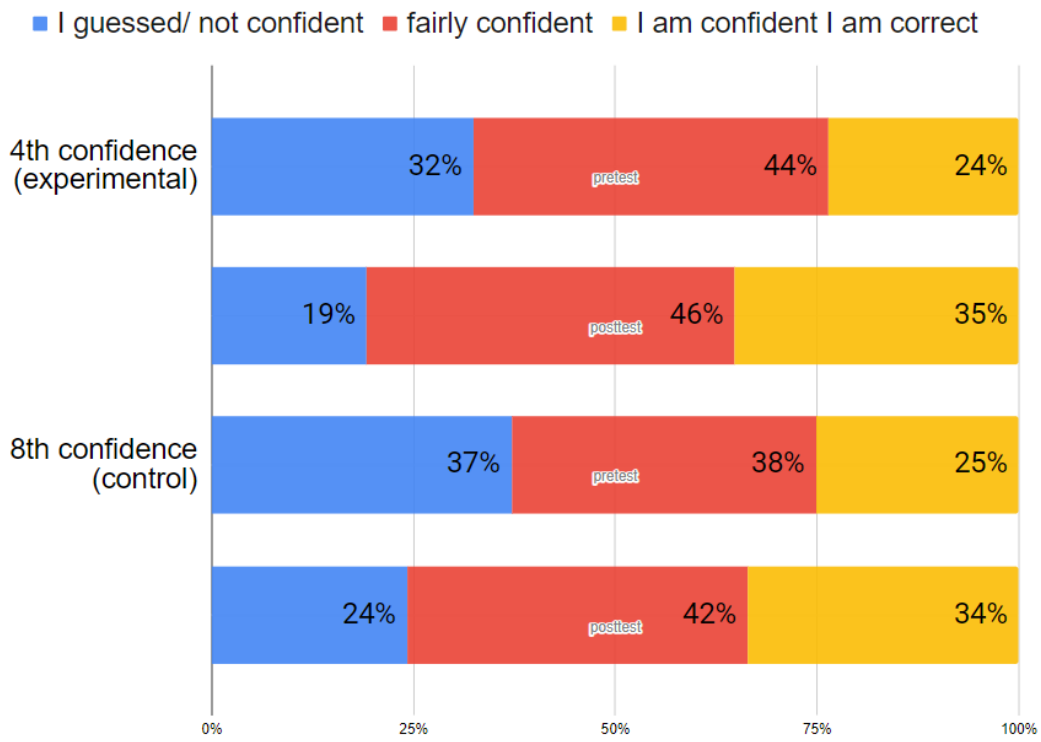


Figure 2. Confidence of mechanisms of Evolution Pretest/Posttest student responses.

Likert Survey

The student Likert survey responses regarding their perception of simulations was then analyzed. Students responded with heavily skewed results towards "strongly agree" and "somewhat agree" indicating students showed a more favorable view towards the use of digital simulations (Table 5). The combined responses of disagree and neutral (range of n=6 to n=7) was half of the responses indicating agreement (range of n=14 to n=15) for the ease of visualizing concepts, student engagement, clarity of topic explanation, and student satisfaction. The only response that showed a strong neutral or negative attitude was regarding the simulations ability to facilitate collaboration, with n=13 indicating disagreement or neutral attitude and n=8 responses indicating agreement.

Table 5. Responses- Likert Survey of Digital Simulations.

	1. The simulation made it easier to visualize the mechanisms of evolution.	2. The simulation was more engaging than discussion-based scenarios.	3. The simulation made it easy to collaborate with others.	4. I gained a clearer understanding of how evolution works using the simulation.	5. I feel satisfied with the experience towards my learning.
strongly or somewhat disagree	2	2	3	2	4
neutral	4	5	10	4	2
strongly or somewhat agree	15	14	8	15	15

Engagement and Accessibility

The engagement and accessibility survey responses were tallied by theme and key word mentions, then ranked and color coded by its view towards technology (Appendix G). The most common barrier mentioned by students was the reliability of the technology and networks. Student responses indicated that “wifi doesn’t work” and that the “internet doesn’t connect.” Students also indicated that the school login accounts were getting locked. This must be reset by library technology staff. However, students did show a positive view towards the ability of technology to facilitate research and improve their overall capacity to stay organized. Students responded that it was “easier to keep things together” and that it can facilitate their ability to stay on track because they can “still get assignments when absent through Schoology.” Many also relayed that they felt it was a faster and easier way to complete assignments and exams, responding that its “easier to take tests.” Several students had responded that they felt technology use must be balanced with more traditional deliveries and that technology should be utilized as a differentiation tool and it should “be made a choice” when and how it is used for assignment completion.

Claims From the Study

The Use of Digital Simulations on Mastery

The overarching goal of my AR study was to identify student perspectives on the usage of technology and its effect on achievement and engagement to determine how to best implement technology moving forward. This study had three specific objectives to accomplish the previously stated goal. The first was to identify if the use of digital simulations increases student understanding compared to paper-based manipulative simulations. Student mastery showed increased gains with digital simulations as indicated on the pretest and posttest questions. In addition, they reported an increased confidence in their responses compared to the paper-based group. This indicates that student achievement was improved with the use of digital simulations in the science classroom compared to paper-based simulations. This supports the conclusions of studies conducted by Blood and Neel (2008) and Louca and Zacharia (2011). As simulations fall under the second domain of the T3 framework, the increased engagement also supports claims outlined by Magana (2017).

The Use of Digital Notetaking on Mastery

The second objective was to determine if the use of a mixture of digital response systems and paper-based notes would show higher student mastery when compared to computer-based notetaking strategies. Based on student pretest and posttest performance on the Evidence of Evolution assessment tool, students showed less mastery gains taking notes digitally than on paper. This indicates that student achievement and mastery are

higher using a mixture of traditional paper-based notes with interactive digital response systems than using computer-based notetaking strategies alone. This study reinforced the results of previous studies of Morehead and Rawson (2019) and Mueller and Oppenheimer (2014). Notetaking falls under the first domain of the T3 framework, which claims that purely digital notetaking reduces engagement in students (Magana 2017). This generally is reinforced by my studies results, although about 1 in 4 students did indicate a preference for digital notetaking on their surveys. This method could be made optional and utilized as a differentiation tool in the future.

Technology Usage and Student Satisfaction and Engagement

The last objective was to determine if students felt a higher level of engagement and satisfaction with their learning experience with the use of digital simulations and notes than traditional paper-based methods. Students reported an increased level of engagement and satisfaction with the digital simulation on the Likert survey. However, about 3 in 4 students do not prefer to take notes digitally according to their Likert survey. On the student open-response survey, many reported a strong to moderate disengagement and challenges with digital notetaking stating that digital notetaking was not as personal as paper-based notes, was confusing to format, and was tough to stay focused on.

Value of the Study and Consideration for Further Research

While this study supports that computer-based simulations provide higher engagement and mastery than paper-based activities, I would like to look closer at how digital simulations can be utilized as an addition to paper-based activities to further

student engagement and comprehension. The utilization of both in slightly different ways may yield the maximum benefit, as suggested by Hattie (2017).

In the Likert surveys and open responses, there was a clear indication that students favored paper notetaking. However, some students did indicate a preference for digital notetaking on their Likert and open-response surveys. To better understand this variance of responses, further study can be done to determine if these preferences show a correlation to learning styles. Other factors that were not taken into consideration for this study that warrant further examination include the students current level of knowledge and skill, and the students home access and engagement with technology.

The open-response survey also identified other areas of interest for continued study including how technology can facilitate learning and engagement in collaborative project-based learning and research, and how computer-based test-taking can affect integrity of data on standardized exams. Further, the biggest challenge expressed by students was reliability of internet and the ability to navigate the computer itself. These concerns will be passed along to the district level for further evaluation to determine what infrastructure supports may be necessary to upgrade or alter in order to further facilitate technology integration.

Impact of Action Research on the Author

Several things changed throughout the Covid pandemic that affected how teachers can engage and interact with their students. Technology became a primary facilitator and the shift to technology integration was so rapid and immense that it became overwhelming to navigate for many educators. Being able to conduct this study provided

a methodical means of analyzing key areas of technology integration in the science classroom in the best interest of the students.

While initially I sought out to determine key areas where technology could best be integrated, the open-response survey made me come to a different realization. Technology is not a replacement for traditional methods, but rather another tool in the toolbox to allow for greater differentiation in the classroom. Several students favored either just traditional or just technology mediated learning, however most indicated that their preference varies by situation, writing “both have their benefits” and “it could depend on what kind of assignment it is.” It made me realize that seeking to turn technological options into another “one size fits all” approach is in opposition to the very core of being a successful educator. That is, that each student is unique and deserves an education that is meaningful and often as unique as they are. As one student put it “Shouldn't letting the students learn the way they feel most confident in be most important?” This is something to reflect upon when we as educators launch new initiatives or incorporate new strategies and frameworks. While the novel technologies and techniques may work for many, they may not be right for all students and all situations and by making items mandatory and using a “blanket approach” we are not necessarily working in the best interest of our diverse student populations.

REFERENCES CITED

Allen, M. (2017). *The SAGE encyclopedia of communication research methods* (Vols. 1-4). SAGE Publications, Inc. https://10.4135/9781483381411

Blood, E., & Neel, R. (2008). Using student response systems in lecture-based instruction: Does it change student engagement and learning? *Journal of Technology and Teacher Education, 16*(3), 375–383. https://eric.ed.gov/?id=EJ797352

Bowen, M., & Bartley, A. (2014). *The basics of data literacy: helping your students (and you!) make sense of data.* NSTA Press

Bryce, C., Baliga, V., De Nesnera, K., Fiack, D., Goetz, K., Tarjan, L., Wade, C., Yovovich, V., Baumgart, S., Bard, D., Ash, D., Parker, I., & Gilbert, G. (2016). Exploring models in the biology classroom, *The American Biology Teacher 78*(1), 35-42. https://doi.org/10.1525/abt.2016.78.1.35

Ector County Independent School District. (n.d.) ECISD quick facts/District overview. https://www.ectorcountyisd.org/Page/5026

Gallup Inc. (2019). *Education technology use in schools*. Gallup.

Given, L. M. (2012). The SAGE encyclopedia of qualitative research methods. SAGE publications, Inc. https://dx.doi.org/10.4135/9781412963909

Grabau. L., & Ma, X. (2017). Science engagement and science achievement in the context of science instruction: A multilevel analysis of U.S. students and schools, *International Journal of Science Education, 39*(8),1045-1068. https://doi.org/10.1080.09500693.2017.1313468

Hakami, M. (2020). Using Nearpod as a tool to promote active learning in higher education in a BYOD learning environment. *Journal of Education and Learning 9*(1), https://doi.org/10.5539/jel.v9n1p119

Hattie, J. (2017). *250+ Influences on student achievement*. Visible Learning. https://visible-learning.org/wp-content/uploads/2018/03/VLPLUS-252-Influences-Hattie-ranking-DEC-2017.pdf

Halverson, L.R., & Graham, C.R. (2019). Learner engagement in blended learning environments: A conceptual framework. *Online Learning, 23*(2), 145-178. https://doi.org/10.24059/olj.v23i2.1481

Louca, L. & Zacharia, Z. (2011). Modeling-based learning in science education: Cognitive, metacognitive, social, material and epistemological contributions. *Educational Review, 64*(4), 474-492. https://doi.org/10.1080/00131911.2011.628748.

Magana, S. (2019). *Disruptive classroom technologies: A framework for innovation in education*. Corwin.

Mertler, C. A. (2020). *Action research: Improving schools and empowering educators (6th ed).* SAGE publications, Inc

Morehead, K., Dunlosky, J., & Rawson, K. (2019). How much mightier is the pen than the keyboard for note-taking? A replication and extension of Mueller and Oppenheimer (2014). *Educational Psychology Review, 31,* 753-780. https://doi.org/10.1007/s10648-019-09468-2

Panorama Education. (2020). How a survey of 34,000 students is informing Ector County ISD's reopening plans. https://www.panoramaed.com/blog/ecisd-distance-learning

Poirier, C. R., & Feldman, R. S. (2007). Promoting active learning using individual response technology in large introductory psychology classes. *Teaching of Psychology, 34*(3), 194-196. http://doi.org/10.1080/00986280701498665

Rila, A., Estrapala, S., & Bruhn, A. L. (2019). Using technology to increase opportunities to respond. *Beyond Behavior, 28*(1), 36-45. http://doi.org/10.1177/1074295619835207

Rutten, N., Van Joolingen, & W.,Van der Veen, J. (2012). The learning effects of computer simulations in science education. *Computers & Education, 58*(1), 136-153. https://doi.org/10.1016/j.compedu.2011.07.017.

Schlechty, P. (2011). *Engaging students: The next level of working on the work.* John Wiley and Sons.

Špernjak, A., & Šorgo, A. (2018). Differences in acquired knowledge and attitudes achieved with traditional, computer-supported and virtual laboratory biology laboratory exercises. *Journal of Biological Education, 52*(2), 206-220. http://doi.org/10.1080/00219266.2017.1298532

Spiezia, V. (2010). Does computer use increase educational achievements? Student-level evidence from PISA. *OECD Journal: Economic Studies, 2010.* https://dx.doi.org/10.1787/19952856

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research, 81*(1), 4–28. https://doi.org/10.3102/0034654310393361

Texas Education Agency (TEA). (2020). STAAR science resources. https://tea.texas.gov/student-assessment/testing/staar/staar-science-resources.

Texas Tribune. (2019). Texas tribune public schools explorer: Ector County ISD. https://schools.texastribune.org/districts/ector-county-isd/

Vogt, W. P. (2011). SAGE quantitative research methods. https://10.4135/9781506326139.n280

APPENDICES

APPENDIX A

IRB EXEMPTION

MONTANA STATE UNIVERSITY
Request for Designation of Research as Exempt
MSSE Research Projects Only
(6/16/14)

****

THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.
Confirmation Date: 12/13/21 Mark T. Quinn
Application Number:

****

DATE of SUBMISSION: 12/1/2021

-Okay as exempt
-MSSE Classroom assessment
-Little/no risk
-Principal awaiting IRB approval
-No concerns
MQ 12/13/21

Address each section – do not leave any section blank.

I. INVESTIGATOR:

Name: **Jennifer Livesay**
Home or School Mailing Address: **Permian High School, 1800 E. 42nd St. Odessa, TX 79762**
Telephone Number: **(479)330-0610**
E-Mail Address: **jmariehohn@gmail.com or jennifer.livesay@ectorcountyisd.org**
DATE TRAINING COMPLETED: **29-Nov-2021** *[Required training: CITI training; see website for link]*

Investigator Signature *Jennifer Livesay*

Name of Project Advisor: **Dr. Jessi Anderson**
E-Mail Address of Project Advisor: **jessica.anderson40@montana.edu**

II. TITLE OF RESEARCH PROJECT: **The Impact of Technology on Engagement and Content Mastery in High School Biology**

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a survey/questionnaire, provide a copy).
Student gains in mastery between experimental and control groups will be determined by pretest/posttest assessments. Student engagement feedback will be obtained through two Likert surveys and an open-response survey.

IV. RISKS AND INCONVENIENCES TO SUBJECTS: **No known risks**

V. SUBJECTS:

A. Expected numbers of subjects: **70**

B. Will research involve minors (age <18 years)? **Yes** No
(If 'Yes', please specify and justify.)

C. Will research involve prisoners? Yes **No**

D. Will research involve any specific ethnic, racial, religious, etc. groups of people?
(If 'Yes', please specify and justify.) Yes **No**

VI. FOR RESEARCH INVOLVING SURVEYS OR QUESTIONNAIRES:

APPENDIX B

MECHANISMS OF EVOLUTION (PRETEST/POSTTEST)

1) The ability of an organism to compete successfully for environmental resources, survive predation, resist disease, and live to adulthood affects the organism's —
    a. fitness
    b. genetic variability
    c. reproductive potential
    d. genetic code

2) Evolution that occurs due to an individual migrating and mating in a new population is known as-
    a. Gene flow
    b. Genetic drift
    c. Natural selection
    d. Nonrandom-mating

3) Which of the following are environmental factors that can select for or against certain traits? **Choose all that apply**.
    - Predation
    - Vegetation
    - Temperature
    - Precipitation
    - Availability of mates

4) Which mechanism of evolution leads to adaptations?
    a. Gene flow
    b. Genetic drift
    c. Natural selection
    d. Non-random mating

5) True or false: Only beneficial traits are passed on to the next generation.
    a. True
    b. False

6) Which of the following best explains why a finite supply of environmental resources is important to differential reproductive success?
    a. Limited resources create selection pressures for survival on the population.
    b. Variations within a population allow for differential reproductive success.
    c. Some members of a population survive competition but never reproduce.
    d. Natural selection does not occur when the environment limits the supply of resources

7) Natural selection relates to adaptations in all the following ways except —

a. adaptations that cause a disadvantage to the species are selected against and do not become common in the population
b. organisms with traits that best enable them to adapt to an environment are the ones most likely to survive
c. natural selection grants a species any trait it might need for survival
d. changes that make organisms better suited to their environment become common in the species

8) Which of the following is an example of a heritable characteristic possessed by an animal that will improve its reproductive potential and survivability in its environment?
   a. Position of geese flying in V formation
   b. Color and shape camouflage of a preying mantis
   c. Use of tools by chimpanzees learned through experience
   d. Male dominance in a pack of wolves

9) What conclusion can be drawn from the following statements regarding the adaptation of organisms?

   1. Variation exists among individuals in a population.
   2. Genes are passed from one generation to the next.
   3. Speciation occurs when variation occurs over time in geographic isolation.

   a. Organisms adapt to changes in the environment on an individual basis.
   b. Adaptation leads to change in a species.
   c. Variation is caused by a single factor.
   d. Species only adapt when they make the decision to adapt.

10) For a mutation to be evolutionarily significant, it must —
   a. change the type of protein being produced
   b. have a neutral effect on an organism
   c. provide a survival advantage to the species
   d. cause the loss of a gene

APPENDIX C

LIKERT SURVEY OF COMPUTER-BASED SIMULATION LEARNING

1. The simulation made it easier to visualize the mechanisms of evolution.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
2. The simulation was easy to navigate.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
3. The simulation was more engaging than discussion-based scenarios.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
4. The simulation made it easy to collaborate with others.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
5. I gained a clearer understanding of how evolution works using the simulation.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
6. I feel satisfied with the experience towards my learning.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○

APPENDIX D

EVIDENCE OF EVOLUTION (PRETEST/POSTTEST)

Species	Nucleotide Sequences
Species 1	ATGTAGC
Species 2	ATCTGAC
Species 3	AGGTACC
Species 4	AGGCGGC

1) The table above shows a section of DNA for four different species. According to this data, which two species are most closely related? **Select two answers below.**
   - Species 1
   - Species 2
   - Species 3
   - Species 4

2) The occurrence of the same amino acid sequence in digestive proteins in two morphologically unrelated species provides evidence that these two species —

   a. occupy the same niche
   b. have analogous structures
   c. descended from a common ancestor
   d. have evolved convergently

3) How can evolutionary relationships among organisms be determined by comparing embryonic development?

   a. Embryos retrace their ancestral stages during embryonic development.
   b. Embryos of more closely related organisms show greater similarities in development.
   c. Embryos that develop inside eggs lack similarities to placental mammals.
   d. Both fish and humans have a two chambered heart in an early stage of development.

4) Looking through the fossil record, there are times when numerous fossils look to just appear all at the same time with similar characteristics. What is a good explanation for this?

    a. A change in the environment occurred, and animals choose to express different traits.
    b. New species are always occurring, and there is no reason for it.
    c. Ancient man killed off all the animals, and they raised new animals, which are then found in the fossil record.
    d. A change in the environment caused a new trait to be favored for survival.

5) What is the best explanation for the different types of beaks in the finches?

    a. Each species of finch was brought to the islands by explorers over the course of several decades.
    b. The finches can adjust their beak type depending on what predators are hunting them.
    c. The type of beak on each individual finch depends on what mutations that finch receives during reproduction.
    d. Natural selection caused each species of finch to have the type of beak best suited for survival in its environment

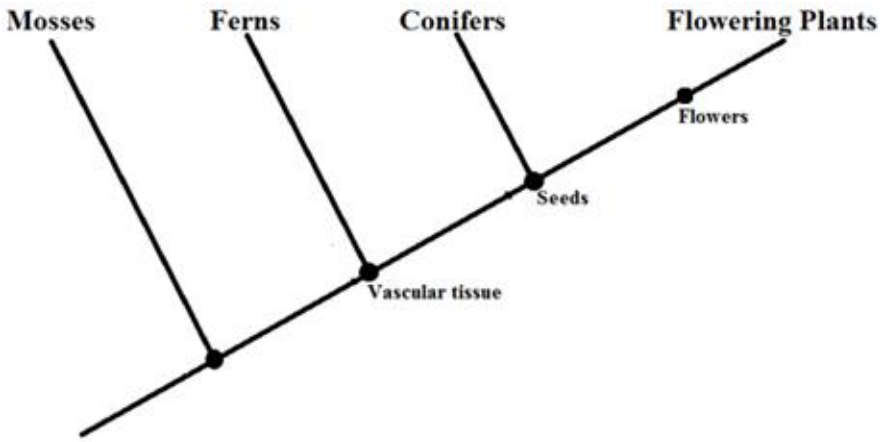
6) The three illustrations show anatomical structures of three different organisms.

1 2 3

Based on your understanding of anatomical homologies, which organisms most likely have a recent common ancestor?

    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. None of the organisms have a common ancestor.

A student created a cladogram for several types of plants. Use the cladogram to answer 6-8.

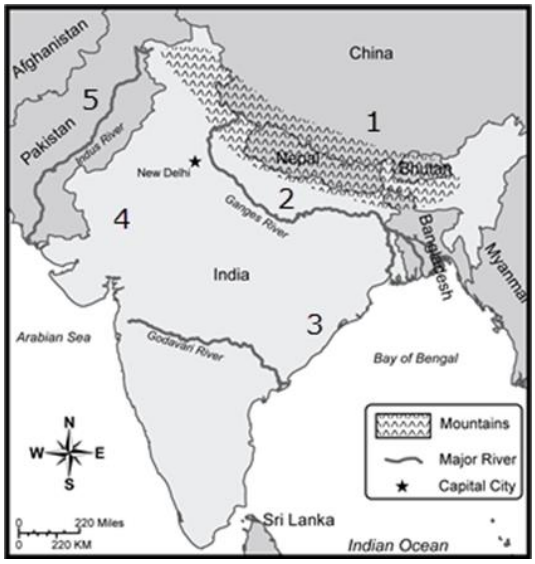


7) Which organisms produce seeds? **Select all that apply.**
   - Mosses
   - Ferns
   - Conifers
   - Flowering plants

8) Which organism is most related to mosses?
   a. Ferns
   b. Conifers
   c. Flowering plants
   d. All are equally related

9) What kind of evidence would challenge the accuracy of the cladogram?
   a. The discovery of a species of conifers that contained vascular tissue
   b. The discovery of a species of ferns that produced seeds
   c. The discovery of flowering plants with vascular tissue and seeds
   d. The discovery of a species of mosses that lacked flowers

10) A map of an area of the world with a key showing geographic features is labeled with several numbers. The numbers represent populations of species that all have common ancestry with each other.



Based on the geographical features, which two species are likely to have the most recent common ancestor?

a. 1 and 2
b. 2 and 3
c. 3 and 4
d. 4 and 5

APPENDIX E

LIKERT SURVEY OF COMPUTER-BASED NOTETAKING

1. It is easier to take notes digitally than on paper.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
2. I gained a higher mastery of content taking notes digitally than on paper.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
3. Digital notes are easier to access when needed for studying and assignment completion.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
4. Digital notes are easier to personalize than paper notes.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
5. Digital notes are easier to organize. (Example: by topic, unit, or level of understanding.)				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree ○
6. I feel satisfied with the experience towards my learning.				
Strongly Disagree ○	Somewhat Disagree ○	Neutral ○	Somewhat Agree ○	Strongly agree

APPENDIX F

OPEN ENDED SURVEY OF STUDENT ENGAGEMENT AND ACCESSIBILITY

Answer the following as completely as you can regarding the use of technology in the classroom. Things to think about include laboratory activities, simulations, response systems, notes, connectivity, Schoology, etc.

1. Tell me about your experience with technology in school.
    a. What difficulties do you have using technology in school?

2. What aspects of using technology during assignments do you find the most helpful? Least helpful?

3. What do you feel benefits your learning the most, computer-based assignments or traditional paper-based ones? Why?

4. Describe your level of engagement when using a computer-based assignment versus a paper-based assignment.

5. In what ways do you think computer-based assignments could be best incorporated into assignments to benefit your learning?

6. Is there anything else you would like me to know about how you use or feel about technology in the classroom?

APPENDIX G

OPEN ENDED SURVEY DATA ANALYSIS

SURVEY QUESTION	MENTION FREQUENCY
1. Tell me about your general experience with technology in school. What difficulties do you have using technology in school?	
no problem	29
wifi/slow internet	28
charging/hardware	7
knowledge of computer	6
2. What aspects of using technology during assignments do you find the most helpful? Least helpful?	
organization of work	17
research/editing/resources	15
typing faster than writing	9
application issues/connectivity issues	14
physical exhaustion/ distractions	5
cheating easier	3
3. What do you feel benefits your learning the most, computer-based assignments or traditional paper-based ones? Why?	
general preference: computer	24
organization	10
easier/faster	9
research/resources	8
general preference: paper	23
visualization/focus	13
notes/organization	7
peer to peer/ peer to teacher interactions	5
4. Describe your level of engagement when using a computer-based assignment versus a paper-based assignment.	
computer positive/ paper negative	23
computer negative/ paper positive	15
depends on the situation/ both equally	12
5. In what ways do you think computer-based assignments could be best incorporated into assignments to benefit your learning?	

videos/animations/interactive slides	10
missing work/additional resources	9
research	8
6. Is there anything else you would like me to know about how you use or feel about technology in the classroom?	
no response	54
balancing computer work with paper work	4
tech use should be a choice (differentiation)	4