A STUDY OF STUDENT ENGAGEMENT IN

TRADITIONAL AND BLENDED HIGH SCHOOL PHYSICS COURSES

by

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ABSTRACT

Online classes are often less engaging for students and result in lower levels of content knowledge. The goal of this study was to assess the level of student engagement and the level of content knowledge obtained between online lab simulations and traditional, hands-on labs, as well as determine which type of activity is more engaging for a traditional physics student compared to a student in a BlendEd physics course (partially online and partially in-person). Data was collected over two units of instruction from surveys, formative assessments, summative assessments, the learning management system called Canvas, and direct instructor observations. Traditional, hands-on labs were found to be more engaging on average for both traditional and BlendEd physics students, and they resulted in higher levels of content knowledge compared to the online simulations. The most successful BlendEd students were able to work well independently and reported high levels of engagement for the online simulations in addition to the traditional, hands-on labs.

INTRODUCTION AND BACKGROUND

Context of the Study

For the last three years, I have taught regular high school physics and a high school-level astronomy course at Copper Hills High School (CHHS) in West Jordan, Utah. In the 2020-2021 school year, 21 science courses were offered to students at CHHS, including concurrent enrollment, advanced placement (AP), elective sciences, career and technical education (CTE), and the Blended Education (BlendEd) science courses, which will be explained shortly. CHHS uses a block schedule, where A days have periods 1-4 and B days have periods 5-8, which allows each period to be about 80 minutes. A and B days alternate throughout the school year. The school day starts at 7:30 a.m. for both A and B days. Because of the COVID-19 pandemic, we had a modified schedule where Fridays were set aside completely for teacher preparation and collaboration in the morning, with student intervention time in the afternoons where students could come in to make up work or get help.

In the last five years of my teaching career, I have learned that giving myself opportunities to learn and stretch my abilities is highly beneficial to me, so when my administrative team or the district asks for volunteers to do innovative things, I like to say yes when I can. In the fall of 2019, the Jordan School District superintendent, Dr. Anthony Godfrey, asked all of the high school administrative teams in the district to offer Blended Education (BlendEd) courses in their high schools starting in the 2020-2021 school year. As a result, my school principal, Bryan Veazie, asked for teachers in the school to volunteer to help start the program. I accepted the invitation to create a BlendEd

Physics class, in addition to continuing to teach traditional physics and astronomy. Seven other teachers in the school also offered to teach BlendEd classes, resulting in a wide range of offered courses including math, language arts, history, and chemistry.

The idea behind blended learning is to give students more freedom and options in their learning experience. There are many blended learning models in education, but for the purpose of this project, I will explain how blended learning looks for my high school, district, and for my own physics BlendEd class in particular. Dr. Godfrey wanted to give our district's students more options for how they will fulfil their graduation requirements. It has been a long-standing issue that the first period of the school day is often difficult for many students--either because they are still tired and fall asleep in class, or because they are often late to school for various personal reasons. Dr. Godfrey wanted to give students a late start option without cutting into their educational day, and blended learning seemed like it could solve that problem.

All blended learning courses are some combination of online learning and in-person collaborative learning. The BlendEd classes being offered at CHHS and throughout the district are meant to be a 1st or 5th period class (or a 9th period after school in some cases) that students have on their master schedule, but they do not have to attend that period every day. The BlendEd courses are largely online and are accessed through the learning management system (LMS) called Canvas. Each BlendEd course at CHHS looks a little different in regards to how much time is spent in the classroom versus on Canvas, depending on the state curriculum requirements for each course. I am the only teacher at CHHS teaching BlendEd Physics, and only one period of it is offered currently: 5th period, which is the first period of the day on B-days. In the case of BlendEd Physics, learning content takes place mostly online, with hands-on, collaborative science experiences (lab activities) happening inside the classroom about every other week. These lab activities are scheduled for certain days, and students are required to come to class on those days. In addition to having scheduled lab days, students have the option of coming to class during any 5th period to get personalized, one-on-one intervention from me.

The purpose of the BlendEd classes at CHHS is to give students the option to have the freedom of an online class with the support system of a traditional, brick-and-mortar class. A purely online class has some drawbacks: while it gives the student the autonomy to learn when learning is best for them, they often lack an adequate support system from the instructor, peers, and the school itself, and students often find that online classes are less engaging which impairs their learning experience. On the other hand, while the traditional classroom can have excellent support systems for students, it does not lend itself well to every kind of learner--for example, some students struggle to engage themselves early in the morning, or perhaps they struggle to focus when they are in a classroom with 40 other students. What it comes down to is that there are many kinds of learners in the world, and education should not cater to only one kind of student. Blended learning is simply another option to give as many students as possible the education that they need.

Before the 2020-2021 school year, I had very little experience teaching online courses, and what I was most concerned about with teaching BlendEd Physics was how to create a course with as much or more student engagement as a traditional physics course. I wanted to find the perfect balance between giving students autonomy with their learning and engaging them in the learning process in an effective way that would increase academic achievement (scoring high on formative and summative assessments which translates to learning the content well). I was also concerned about what personal situations lead students to want to take a BlendEd course and how those situations affect the educational experience of those students. Specifically, I want to see if there is a correlation between personal student situations and how those situations affect student engagement in the course and academic achievement.

My hope with this research project was to learn how to give different kinds of students effective learning experiences. Because this blended learning initiative was new to myself, my colleagues, and my administrative team, the information I learned about how to effectively engage my students in this course and foster high academic achievement will be used to help myself and my colleagues teach these courses more effectively in the future. The more engaged my BlendEd students are with their learning, the better they will remember the things that they learn in the class. Additionally, many of the BlendEd students had never taken online classes, so I hoped that giving them a positive experience with adequate supports in place would give them more confidence when taking online courses in the future.

Focus Statement and Research Questions

The focus of this study was to determine how student engagement affects academic achievement in both BlendEd Physics and a traditional physics course. In addition to this focus statement, the following sub-questions were addressed:

Sub-question 1: How do hands-on, traditional labs compare to online lab simulations in fostering high student engagement in a traditional physics class and a BlendEd physics course?

Sub-question 2: How do hands-on, traditional labs compare to online lab simulations in fostering high academic achievement in a traditional physics class and a BlendEd physics course?

Sub-question 3: How do the personal situations of students in the BlendEd Physics course affect student engagement and academic achievement?

CONCEPTUAL FRAMEWORK

In this section, I will discuss the conceptual framework that surrounds my research. I found that the idea of student engagement is quite broad, and I have narrowed that field to three subsets: behavioral, emotional, and cognitive engagement. This section will also discuss how engagement works for students in a virtual setting, and what methods other researchers have used to measure engagement.

The Three Subsets of Student Engagement

The following is a well-established fact that any teacher would tell you: the more engaged a student is in the learning process, the better they will learn. There have been countless studies that all conclude the same thing, spanning from the 1960s to now. For example, an article by Klem and Connell (2004) wrote that students engaged in school are more likely to earn higher grades and test scores, and have lower drop-out rates. Their study consisted of assessing the engagement of elementary and middle school students, both with teacher-reported engagement and student-reported engagement, and comparing that to overall academic success. In both the elementary and middle school studies, more highly engaged students earned higher grades and test scores. This is just one of many research studies that have been done on the topic, and almost exclusively, they all have the same conclusion: higher engagement garners higher achievement.

The problem is that the term “engagement” refers to a very broad research topic, and researchers all see to define it slightly differently. Generally speaking, student engagement refers to the degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education (Glossary of Education Reform, 2016). Fredericks et al. (2004) discuss how student engagement should be assessed and researched as a multi-faceted construct that includes behavioral engagement, emotional engagement, and cognitive engagement. Measuring these subsets of student engagement will look different in a traditional classroom compared to an online course. Henrie et al. (2015) used the three subsets of student engagement as described by Fredericks et al. to determine how each subset could be measured and studied.

Behavioral Engagement

Behavioral engagement would include the observable student behaviors that would theoretically lead to academic achievement, including attendance, homework completion, and participation in classroom activities (Fredericks et al., 2004). Measuring behavioral engagement in a traditional classroom looks very different than measuring behavioral engagement in an online course. For example, in a traditional classroom, instructors can produce observational data while watching students participating in classroom activities. In an online environment, however, this is much more challenging as students are not in the same room as the instructor, and are often participating in the class at different times. Henrie et al. (2015) cited examples from other research sources how behavioral engagement was operationalized, including: assignments completed; frequency of logins; attendance; the number, quality and frequency of online posts; and time spent online.

Holmes (2018) researched how student engagement in an online class can increase by using continuous, low-stakes formative assessments instead of high stakes summative assessments. When using the lens of the three subsets of student engagement, it is clear to me that Holmes is referring to behavioral engagement. The study refers to the number of logins and page clicks students make in an online class. Holmes concludes that the more often students engage with the online platform, they reach higher academic achievement based on formative assessment grades.

Emotional Engagement

Emotional engagement includes the feelings that students have about their learning experience, which includes feelings of interest, frustration, or boredom. Emotional engagement also includes feelings relating to social interactions with peers and instructors (Fredericks et al., 2004). Henrie et al. (2015) also cited examples from other research sources how emotional engagement was operationalized, measuring happiness, anxiety, boredom, interest, passion, sense of class community, visible expressions of pleasure, and student-student interactions.

A study done by Northey et al. (2015) suggests that empowering students to co-create the learning experience improves engagement. They suggest that one way to make students stakeholders in their own learning comes from asynchronous instruction, or instruction outside the classroom. They specifically site discussion pages on social media or other virtual environments:

> Students can post comments or pose questions and expect that others will respond when they log on to the same platform. Such asynchronous interaction offers many benefits. By logging on at a self-determined time of readiness, learners also will be more focused on task-specific learning behavior; moreover, because interactions

> within the group are not in real time, students have the opportunity to absorb and consider information before responding. This type of experiential learning leads to more effective learning.

Northey et al. (2015) hypothesize that participation in asynchronous learning positively influences perceived student engagement. As perceived student engagement increases, student motivation and commitment also increase. In the lense of the three subsets of student engagement by Fredericks et al. (2004), the mindset shift would positively affect emotional engagement, since the feelings that students have towards learning would be affected positively: they would feel more involved socially. Interestingly, the authors specifically cite Facebook as a good platform for asynchronous learning to take place. The reason why many students liked using Facebook for these discussions was because they were familiar with it and there was an app that increased convenience. Theoretically, similar to Facebook, the discussion portion of Canvas should feel convenient and familiar to students in the BlendEd courses since there is now an app for it that they can access at any time. The whole premise of this article is that Blended learning can, in and of itself, increase engagement, simply because students have the opportunity to take learning into their own hands.

In order to help me learn more about what is engaging for students, I read a book titled *"Student Engagement Online: What Works and Why*" by Katrina A. Meyer (2014). One suggestion in the book to increase engagement is to focus on students putting forth effort and work--assignments that ask students to do something (work in a group, solve a problem, prepare a project, experience a situation, etc.) will really help engage students. It is also important that every assignment has a "why" that the students understand. After reviewing multiple learning theories, the author boils it down to a few key ideas: instructors need to include experiences that emphasize active learning, collaborative learning, and experiential or transformative learning; course-related experiences ought to engage students with content, other students, and outsiders; and course-related experiences ought to help create a sense of community that has an educational purpose. All of this comes back to emotional engagement as explained by Fredericks et al. (2004): if students are emotionally invested in learning the content because they feel like they are part of a learning community, their engagement will increase.

Cognitive Engagement

The final subset of student engagement is cognitive engagement. Cognitive engagement focuses on the effort learners give to effectively understand what is being taught, including self-regulation and metacognitive behaviors (Fredericks et al., 2004). Henrie et al. (2015) also cited examples from other research sources how cognitive engagement was operationalized, including improved understanding, problem-solving behavior, perceived value or relevance, literate thinking, and challenge.

Henrie et al. (2015) concluded that measuring all three subsets of student engagement (behavioral, emotional, and cognitive) would require quantitative and qualitative self-reporting measures, as well as quantitative observational measures. The most common form of quantitative and qualitative self-reporting was student surveys, though surveys can have drawbacks, such as being tedious and taking time away from student learning opportunities.

Student Engagement in a Virtual Setting

In addition to the theoretical framework for engagement presented by Fredericks et al. (2004), Beer et al. (2010) define the term engagement slightly differently: engagement is seen to comprise active and collaborative learning, participation in challenging academic activities, formative communication with academic staff, involvement in enriching educational experiences, and feeling legitimated and supported by university learning communities. These elements depend on various combinations of social interactions between instructors, students, and content. The authors explain how learning environments directly affect student engagement by setting the stage for how and where these social interactions take place, and in the case of online courses, the LMS being used will be a huge factor.

Typically, engagement in a traditional classroom starts with attendance (Beer et al., 2010). Using that notion, the authors assumed that the equivalent of attendance with online courses is how often students interact with the LMS. This would be related to the Behavioral engagement as defined by Fredericks et al. (2010). Using data from the University, Beer et al. (2010) compared overall grade and number of clicks in the LMS and found a clear correlation: students typically scored higher when they interacted with the LMS more. Interestingly, they also accumulated data showing a correlation between student grades, number of clicks on the LMS, and whether or not the instructor of the course participated in the LMS forum discussions: not surprisingly, when the instructor participated in the online discussions, there were more page clicks. Even though this research only really looked at page clicks in the LMS to indicate engagement, this relates directly to the quantitative observation methods mentioned by Henrie et al. (2015).

Methods of Measuring Engagement

Part of my research is to compare student engagement data to academic achievement data. To give me more examples of how student engagement is measured, I found a study done by Ferebee (2013) in which the author compares student engagement for multiple types of assessments throughout multiple units. The author started the treatment with a student survey to determine the learning styles of the students to determine what students self-identify to be engaging for them. During each unit, the author conducted interviews, reviewed student journals, and administered a "section test" which was short and focused on low-level skills like recall. Each unit culminated in an "authentic assessment" instead of a traditional summative assessment. Student journal entries were meant to assess "student attitudes" towards specific assignments and their understanding of content. The student survey was administered pre-treatment, during treatment, and post-treatment to show change in student engagement and learning styles. The author also provided parent surveys through email to gauge at-home learning involvement. The author used test data from previous school years to compare academic achievement using his new treatment.

Another study by Zupke (2012) showed how student engagement can be measured. The author used student surveys--pre-treatment, during treatment, and post-treatment--to analyze how the use of technology affected student attitudes towards science, as well as to measure engagement. The author compared assessment scores and student attitudes towards the use of technology in the classroom and found a positive correlation. The author also discussed how using interactive technology-based assessments instead of typical formative assessments increases student attitudes toward science and increases overall academic achievement. This study and the Ferebee, T.J. (2013) study both show that in order to determine how the blended learning model is affecting student engagement and achievement will require consistent and concise student surveys, personal interviews, and other forms of qualitative data collection, as well as comparing those results to qualitative academic data (such as comparing summative assessment data with student engagement analysis).

I read a case study done by Mills (2011) that was very similar to how I want to complete my research. The purpose of the study was to compare student academic achievement of online mathematics and science courses to a traditional course. The data collection methods that the author used are similar to what I plan to use with my research, including exit surveys given at the end of the online course, student interviews, and student grades. The student survey was thorough and asked demographic questions, questions about experiences with online education past and present, and a course evaluation. While the survey and this case study didn't specifically measure engagement, the format of the survey would lend itself well to measuring student engagement. The author came to the conclusion that students enrolled in an online class make sufficient academic progress, but that a "hybrid-type" course (i.e. blended learning) may be more effective because many online students missed the teacher-student interaction and having access to a teacher to receive help.

METHODOLOGY

The purpose of this research was to determine if there is a correlation between student engagement and the learning of the content (achievement), and if there is a difference in this relationship between a traditional physics student and a BlendEd physics student. I used surveys, direct observations, data from a learning management system (LMS), formative assessments, and summative assessments to determine any correlation between engagement and academic achievement. Generally speaking, the students in this study were between grades 10 and 12, and typically came from white, lower- to middle-class families. The traditional physics students were typically high-achieving students in previous, different courses, while the BlendEd students were mixed level**.** The research methodology received an exemption from Montana State University's Institutional Review Board (Appendix A).

Demographics

CHHS is one of seven high schools in the Jordan School District, and it serves 2,778 students in grades 10-12. The Jordan School District is mostly suburban and urban communities, and it is one of the fastest-growing school districts in the state of Utah, ranking 4th in Utah in the number of students enrolled. CHHS is a suburban high school with a diversity score of 0.45, which is higher than the Utah average of 0.42 (the diversity score is the calculated chance that two students selected at random would be members of a different ethnic group). Seventy-one percent of the student population is white, with Hispanic at 22%. Twenty-two percent of the student population qualify for free or reduced lunch. CHHS has a higher graduation rate at 91% than the state average of 86%, but students have consistently scored lower in math and reading/language arts proficiency than the state average (Public School Review, 2018).

I only had one period of BlendEd Physics to collect data from, and I chose to use data from only one traditional physics class as my comparison, which was my 7th period. A total of 7 students were enrolled in my BlendEd Physics class, all of whom participated in the research, and 23 students in my 7th period chose to participate. In the BlendEd class, there were 2 female students and 5 male students. In the traditional class, there were 15 female students and 8 male students.

Treatment

In order to gauge how student engagement affects academic achievement in my BlendEd Physics course compared to the traditional physics course, I measured student engagement and academic achievement in both my traditional physics class and the BlendEd class over one term, which consisted of two units of instruction: Unit 1 - Motion and Unit 3 - Momentum. During each unit, students participated in one hands-on, traditional lab, and one online simulation. I chose to compare these two kinds of activities because using online simulations was a suggested teaching strategy for blended learning science courses when our district was first working on curriculum. I felt that one of the biggest drawbacks of taking an online science course was the loss of the lab experience, and I wanted to determine if those online lab simulations could successfully produce the engagement and level of content learning that took place in traditional hands-on labs. While the labs and simulations had different overall learning goals attached to them, the associated learning goals of both were part of the unit summative assessment, which took place at the end of each unit. In that way, I could compare the overall level of understanding of those learning goals after the formative assessments (the labs and simulations) to their level of understanding at the end of the unit. All formative and summative assessments during the research period were the same for both the BlendEd students and the traditional students.

For the hands-on, traditional labs, students were given a research question to answer, and after completing the data collection part of lab, they were required to write a "claim-evidence-reasoning" (CER) response to the original investigative question, which was used to help me determine the level of understanding students had of the content. For the online simulations, students used an online lab simulation website called Explore Learning. The online simulations are called "Gizmos", which were accessed through the Explore Learning website. Students were required to follow a worksheet with instructions as to what they should do with the simulation. They answered written questions by using the simulation, and the answers to those questions were used to assess their level of understanding of the learning goals.

Data Collection and Analysis Strategies

The data collection matrix below includes my primary research question for my action research project along with three sub-questions that will focus my data collection. The matrix includes six methods of data collection that I plan to use. These collection methods were chosen in order to best triangulate and validate the data I collect and support my interpretation of the results.

Table 1. Data Collection Matrix.

Focus Questions	Data Source 1	Data Source 2	Data Source 3	Data Source 4
1. How do hands-on, traditional labs compare to online lab simulations in fostering high student engagement in a traditional physics class and a BlendEd physics course?	Student Surveys	Direct Instructor Observations	LMS Behavioral Data	
2. How do hands-on, traditional labs compare to online lab simulations in fostering high academic achievement in a traditional physics class and a BlendEd physics course?	Formative Assessments	Summative Assessments		
3. How do the personal situations of students in the BlendEd Physics course affect student engagement and academic achievement?	Student Surveys	LMS Behavioral Data	Formative Assessments	Summative Assessments

In the following section, I will describe each data collection method in detail. These five data collection methods were meant to work cohesively to give me clear data correlations and therefore determine how student engagement affects academic achievement in both a traditional classroom and a BlendEd course. When analyzing the data I collected, I compared student engagement ratings (using the surveys, LMS data, and observations) to the formative assessment scores. Additionally, I compared the formative assessment scores to the summative assessment scores to see if there was a correlation between the activities to help learn content and retaining the content. Ultimately, I analyzed the scores for specific learning objectives, and the relative student engagement when learning the content, to conclude whether engagement factors into academic achievement, and compare the traditional student data to the BlendEd student data to see if there was a correlation between student engagement and the type of learning experience. Lastly, I compared student backgrounds to engagement data and academic achievement data to determine if there is any kind of correlation between the type of BlendEd student who does well in the class and feels engaged, and one who does not do well in the class and does not feel engaged.

Student Surveys

One of the primary data collection methods that I used were the self-reported student surveys. Understanding student engagement cannot be based solely on outward observations. Collecting data on the level of emotional and cognitive engagement in particular requires a certain amount of trust that students can accurately assess what they are feeling and sharing those feelings accurately. This is where self-report student surveys came in. I gave each student in both my traditional physics 7th period class (N=23) and BlendEd Physics course (N=7) a total of eight surveys throughout the research period.

Because I needed to compare engagement data to academic data, all surveys included the student names. However, I did not use the students' full names in the data analysis section of this paper, only their initials in order to protect their privacy. All of the surveys were distributed electronically using Google Forms. This kept the data organized electronically, which made analyzing the data easier. Students accessed the link to the Google Forms through the LMS Canvas.

Because the research period took place during the first quarter of the school year, I didn't know my students personally very well while I collected data about student engagement. Therefore, I gave each student a survey at the beginning of the research period which helped me get to know their background (Appendix B). This survey included student experiences with online classes, preferred learning styles, and the student's home situation when it comes to academic support. The main goal with this was to see if there is a correlation between a student's personal situation, their decision to take a blended learning course, and their overall ability to do well in that course.

There were a total of four assignments that I collected data from: two hands-on, traditional labs, and two online lab simulations. These assignments covered two units of instruction, as explained in the treatment section. Each activity had a survey that students took after completing the activity (Appendices C through F). The survey itself consisted of qualitative questions that assessed the three subsets of student engagement: behavioral, emotional, and cognitive. The surveys were the same for each assessment, with the exception that one question at the end specifically asked students how well the activity helped them learn the specific content related to the activity. The survey was given immediately after the assignment to ensure the best recall from students. These surveys were designed to be short to prevent “burnout”, since the students needed to take four activity surveys over the course of the research period.

At the end of the research period, after both units were completed, I gave an exit survey to all students (Appendix G). The purpose of this survey was to learn the overall level of student engagement that occurred throughout the research period. The questions on this survey reflect the level of behavioral, emotional, and cognitive engagement throughout the research period as reported by the student, including questions assessing what types of assignments were the most engaging to them.

I had two main goals when I analyzed the data collected in these surveys: 1) to compare how engaged students felt between the hands-on labs and the online simulations; and 2) to find any correlations between relative levels of engagement for the online simulations and hands-on labs and personal information about the students. In order to address these goals, I looked at the overall levels of engagement for behavioral, emotional, and cognitive engagement using the questions in the activity surveys where students select on a scale of one through five their level of engagement during the activities. Then, I compared the levels of engagement for individual students to their personal situations given in the introductory survey to determine if there were any connections.

My strategy for analyzing and representing the data collected from the student surveys was fairly straight-forward. I averaged the overall engagement levels for students when completing the online simulations and compared that score to the average overall engagement levels when completing the hands-on labs. The scores the students reported were on a scale of 1 through 5, with 5 being that the student felt highly engaged more than 80% of the time. I did this for both units of instruction to look for a correlation between assessment type and level of overall engagement. I graphed those engagement scores to better visualize the difference between the online simulations and the hands-on labs, as well as to compare the reported engagement between the BlendEd students and the traditional students. Additionally, I reported relevant student comments collected from the surveys that related to the experiences of the BlendEd students.

Direct Instructor Observations

In addition to the student surveys, another key part of collecting data about student engagement is to directly observe student behaviors. Even though the surveys reported each student's perspective on their own behavioral engagement, it is better to have an outside perspective as well to compare it with.

As stated previously, there were four activities throughout the research period that I collected behavioral observations about: two hands-on labs and two online simulations. During the hands-on labs, all students were physically in the classroom, including my BlendEd students. Students worked in small groups, and during the course of the lab, I walked around (or sat at my desk) and observed each student's behavior. In a notebook, I wrote down my observations of the behavior of individual students, as well as the group as a whole. I looked for on-task behaviors, such as writing on their lab report, discussing lab data and results with their peers, and asking questions. I also looked for off-task behaviors, such as using a cell phone, talking about unrelated topics, or staring off into space.

Making direct observations of the online simulations was trickier. My 7th period traditional physics class completed one of these simulations in class on computers and the other simulation at home when we went to virtual learning because of the COVID-19 pandemic. I utilized a similar method to what is stated above for that first in-class simulation. Students completed these simulations individually, so I looked for on-task and off-task behaviors of individuals while they completed the assignment. However, my BlendEd students completed these assignments on their own time, so I wasn't able to observe them directly, nor for the second simulation activity for my 7th period.

For this particular instrument, there wasn't a lot of data analysis and representation required. I simply wrote down observations such as, "(student name) was on his phone for approximately 5 minutes, and then returned to work". Relevant observations are explained qualitatively in the data analysis section.

LMS Behavioral Data

Because the BlendEd students do most of their learning outside of the classroom, I cannot make direct observations of their learning behavior. As an alternative solution, I decided to collect user data from the LMS Canvas. This idea came from the research of Henrie et al. (2015) that referenced how behavioral engagement for an online class is related to the frequency of logins on the LMS, and overall time spent online. Beer et al. (2010) had a similar suggestion: that engagement starts with attendance, and the equivalent of attendance for an online class is interaction with the LMS. Therefore, to gauge behavioral engagement, I collected data on the number of page views and "participation" actions that occurred for each student during the research period. This

LMS data was organized electronically in a spreadsheet to make it easier to analyze the data in an effective and clear way. This data was then graphically organized by number of page views in a given time period for each student to compare the number of page views during the unit of instruction to the overall level of learning that occurred to see if there was a correlation.

The analytics system on Canvas collects data on how many page views a student had on a given day, as well as “actions taken” on that day. The actions that Canvas counts are submitting an assignment or quiz, commenting in a discussion, or joining a conference. These statistics were collected and used as behavioral engagement data, which replaces attendance data or participation data in a physical classroom.

Although it has not been mentioned often up to this point in this paper, the COVID-19 pandemic was in full swing during my research period. For most of the research period, students were still attending school in-person, but our administrators strongly encouraged most if not all of our assignments and content to be on Canvas so that if and when we did move to virtual learning, our students would already be comfortable with the process of doing assignments online. Because of rising COVID-19 cases in Utah, we switched to virtual learning for most of Unit 3. It was then that it became important for me to collect LMS behavioral data for my traditional students as well as my BlendEd students. I collected data for which students attended class via Zoom, as well as when students completed their assignments.

<u>Formative Assessments</u>

The formative assessments that I collected academic data from were the same two assignments from each unit that I collected engagement data about: the traditional hands-on lab and the online simulation. As mentioned previously, each lab will have a section where students will need to demonstrate their understanding of the content in how it relates to the activity. This section included an analysis section and CER paragraph where the student is graded on their explanation of the content. There was a section in each unit's summative assessment that related to the content learned in the lab activities, in order to determine how the activity influenced their retention of knowledge.

For Unit 1, the hands-on lab activity was called "Pull Back Car Lab" (Appendix H). Students collected motion data for a toy pull-back car, graphed it, and answered the question, "Do pull-back toy cars accelerate?" They wrote a CER response where they claimed an answer and had to reason why they thought that based on evidence collected during the lab. On the Unit 1 summative test, they were required to look at a graph and be able to tell if the object is accelerating, which is what the learning objective of the lab was.

For Unit 3, the hands-on lab was called "Pumpkin Drop" (Appendix I). It is a famous thing at CHHS--students hear about it from older siblings and friends, and for a lot of students, it's what makes them want to take physics. The objective is to build a contraption that will save a pumpkin being dropped from the roof of the school. Ultimately, the learning goal is to calculate the impulse (change in momentum) of the pumpkin as it hits the pumpkin catcher. In the Unit 3 summative assessment, students were asked to calculate impulse using the change in velocity of a mass, which would directly relate to their objective in the pumpkin drop.

The online simulations were also used as formative assessments. The Unit 1 online simulation was called "Distance-Time Graphs Gizmo" (Appendix J). Students were given a worksheet that showed them critical concepts about motion and position-time graphs using the simulation. On the worksheet, students were required to do certain tasks in the Gizmo and answer questions that would help guide them to the learning objective, which was understanding the relationship between position, time, and velocity. I picked specific questions in the worksheet that would show me if students were understanding that relationship correctly.

The online simulation for Unit 3 had a similar design to the Unit 1 Gizmo assignment. The Unit 3 simulation was called "Air Track Gizmo" (Appendix K), and again, students were given a worksheet that would walk them through certain tasks in the simulation that would lead them to the learning objective: in this case, that the total momentum in a system is always conserved before and after a collision. Again, I chose specific questions in the worksheet to analyze and collect data from to determine the level of understanding students had about the learning objective.

To analyze the data collected from these formative assessments, I rated each student's level of understanding of the specific content on a scale of 1 to 5, 5 being they understood it completely, and 1 being they did not understand at all. I created a spreadsheet where I put a "level of understanding" score next to each student's name, and then I average that score for both the traditional class and the BlendEd class (for students who did not complete the assessment, I left their score blank). I put those averaged scores in the data analysis section of this paper.

Summative Assessments

For both units of instruction, I gave a summative assessment. Having common assessments (both formative and summative) allowed me to compare academic achievement between the BlendEd students and traditional students more accurately. If there is a significant difference between the average summative assessment scores of the BlendEd students and the traditional students, it would indicate which teaching method is more effective for the students currently enrolled in each class.

The summative assessments were broken down into sections based on the learning objectives for each unit. The purpose of this was to more easily see which learning objectives were met by each student. Using this information, I was able to determine which sections and assignments of the unit are less effective at teaching the learning objectives, and more specifically, compare the effectiveness of the online simulations and the hands-on labs for teaching that content. In order to eliminate bias as much as possible, the test was distributed to both the BlendEd and traditional students using Canvas. The traditional students took the Unit 1 summative test on computers during class, and took the Unit 3 test at home during virtual learning due to the soft-closure of CHHS during the COVID-19 pandemic. The BlendEd students completed both summative assessments at home on computers.

For the Unit 1 summative test, I chose 6 questions on the test that I felt really matched the learning objectives for the two formative assessments (3 questions for each learning objective). Three questions were chosen to analyze student understanding of the relationship between position, time, and velocity, and the other three questions were chosen for the acceleration learning objective. I made a note of the answer each student selected for each question, looked for common mistakes, and of course which students got the question right. I compared the overall average accuracy for each learning objective for both the BlendEd and traditional students. I used a similar method for the Unit 3 summative test. I selected three questions that showed understanding of calculating impulse, and three questions for the conservation of momentum.

To more easily analyze the data collected, I created a spreadsheet with each student's name and marked which questions the student got right. Since each learning objective had three questions that I was assessing, I average the relative accuracy of each question, and then calculated the overall accuracy of students for that learning objective. This data is organized in a table in the data analysis section.

DATA ANALYSIS

Results

In this section, I will show engagement and content knowledge data for each formative assessment in Unit 1 and Unit 3, and compare this data to the content knowledge data collected from the unit summative assessment. I will then summarize the trends found between the engagement data and the content knowledge data. I will also discuss the qualitative data collected from the surveys about the personal situations of my BlendEd students in order to compare it to their overall engagement and content knowledge. Claims for this study's three focus questions are also summarized in this section. Lastly, there is a brief statement about how the COVID-19 pandemic affected my data collection and results.

Unit 1 Motion Data

Unit 1 was about understanding motion. The two formative assessments chosen were #1 Distance-Time Graphs Gizmo (the online simulation) and #2 Pull-Back Cars Lab (the traditional hands-on lab). After each formative assessment, I gave students a survey in order to assess their own personal feelings of engagement during the activity. The survey for #1 Distance-Time Graphs Gizmo gave the engagement data found in Figure 1 as reported by students on a scale of 1 to 5, 5 being very high levels of engagement throughout the activity.

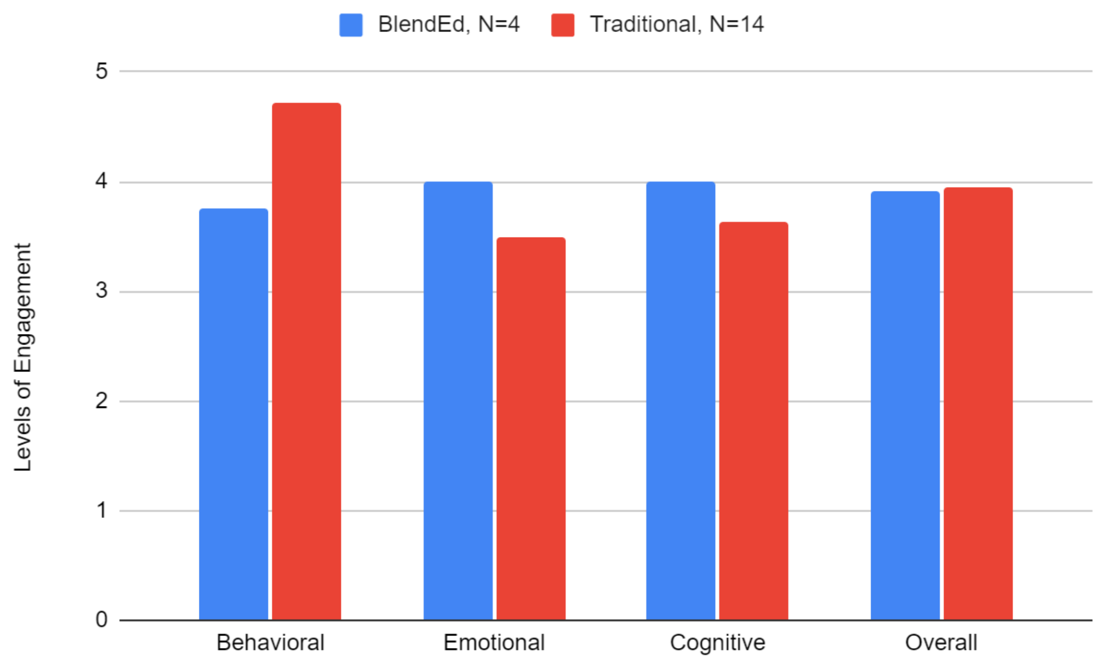

Figure 1. Levels of behavioral, emotional, and cognitive engagement for #1 Distance-Time Graphs Gizmo as reported by the students.

In order to assess how well students understood the content of #1 Distance-Time Graphs Gizmo, I chose a few specific questions from the assignment to rate the level of student understanding. I rated their understanding of the relationship between position, time, and velocity on a scale of 1 to 5, 5 being fully understood the relationship as shown graphically, and 1 being did not understand the relationship at all. These results are summarized in Table 2.

Table 2. Number of students who scored a specific rating of understanding of the graphical relationship between position, time and velocity from #1 Distance-Time Graphs Gizmo formative assessment.

	1	2	3	4	5	Average Class Rating
BlendEd, *N*=5	0	0	0	3	2	4.4
Traditional, *N*=20	0	0	2	9	9	4.35

In the survey for #1 Distance-Time Graphs Gizmo, I asked students to rate the usefulness of the activity on a scale of 1 to 5, 5 being very helpful and 1 being not helpful at all, in helping them grow their understanding of the relationship between position, time, and velocity (Figure 2).

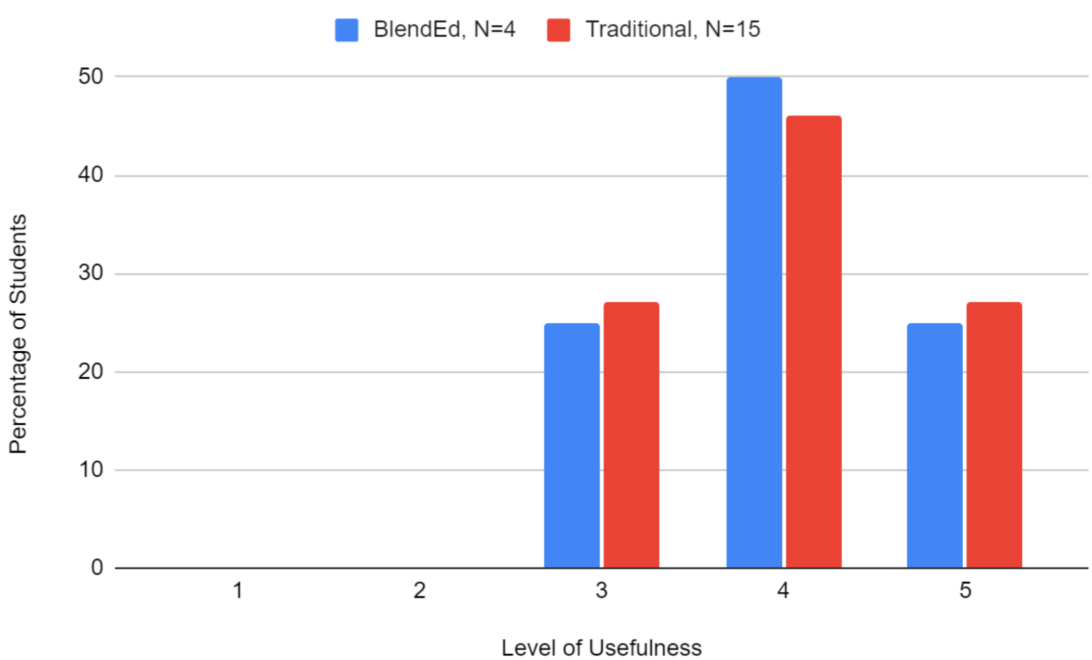

Figure 2. Student reported rating of the usefulness of #1 Distance-Time Graph Gizmo for growing student understanding of the relationship between position, time, and velocity.

Two weeks after students completed #1 Distance-Time Graphs Gizmo, students completed #2 Pull-Back Cars lab, which was the traditional hands-on lab. Students were given the #2 Pull-Back Cars Lab survey to assess their personal feelings of engagement during the activity on a scale of 1 to 5, 5 being very high levels of engagement throughout the activity, and that data is summarized in Figure 3.

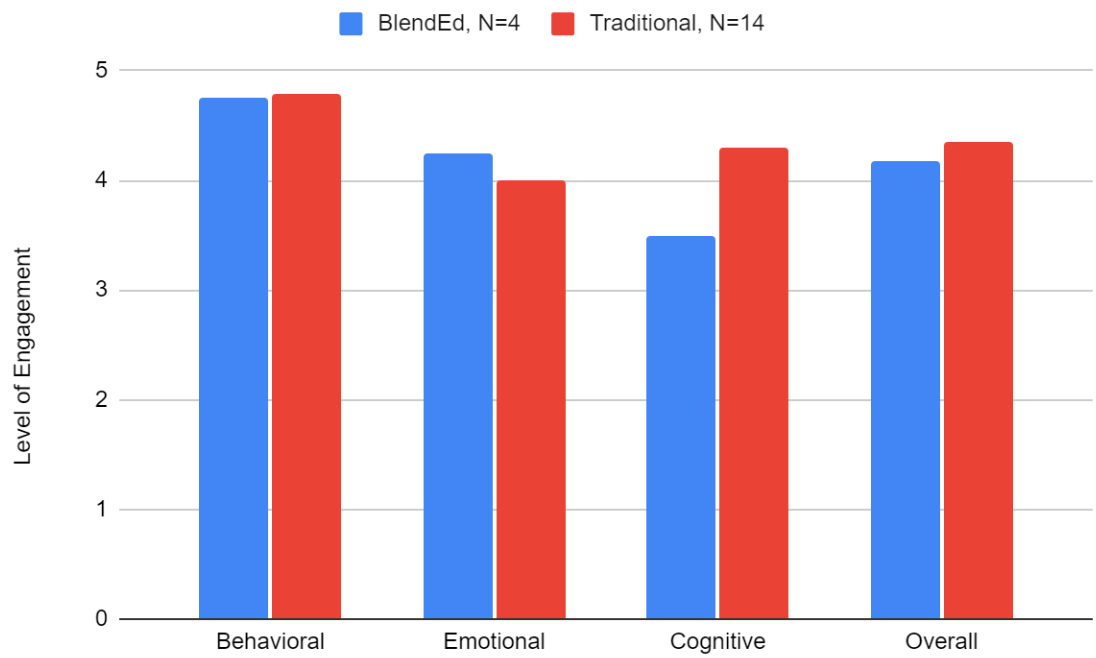

Figure 3. Levels of behavioral, emotional, and cognitive engagement for #2 Pull-Back Cars Lab as reported by the students.

In order to assess how well students understood the content of #2 Pull-Back Cars Lab, I chose a few specific questions from the assignment to rate the level of student understanding. I rated their understanding of the concept of acceleration on a scale of 1 to 5, 5 being fully understood acceleration is any change in velocity, and 1 being did not understand acceleration at all. These results are summarized in Table 3.

Table 3. Number of students who scored a specific rating of understanding acceleration from the #2 Pull-Back Cars Lab formative assessment.

	1	2	3	4	5	Average Class Rating
BlendEd, *N*=6	1	0	1	1	3	3.83
Traditional, *N*=21	4	2	1	7	7	3.52

In the survey for #2 Pull-Back Cars Lab, I asked students to rate the usefulness of the activity in helping them grow their understanding of acceleration, 5 being very helpful and 1 being not helpful at all. Those rating results are shown in Figure 4.

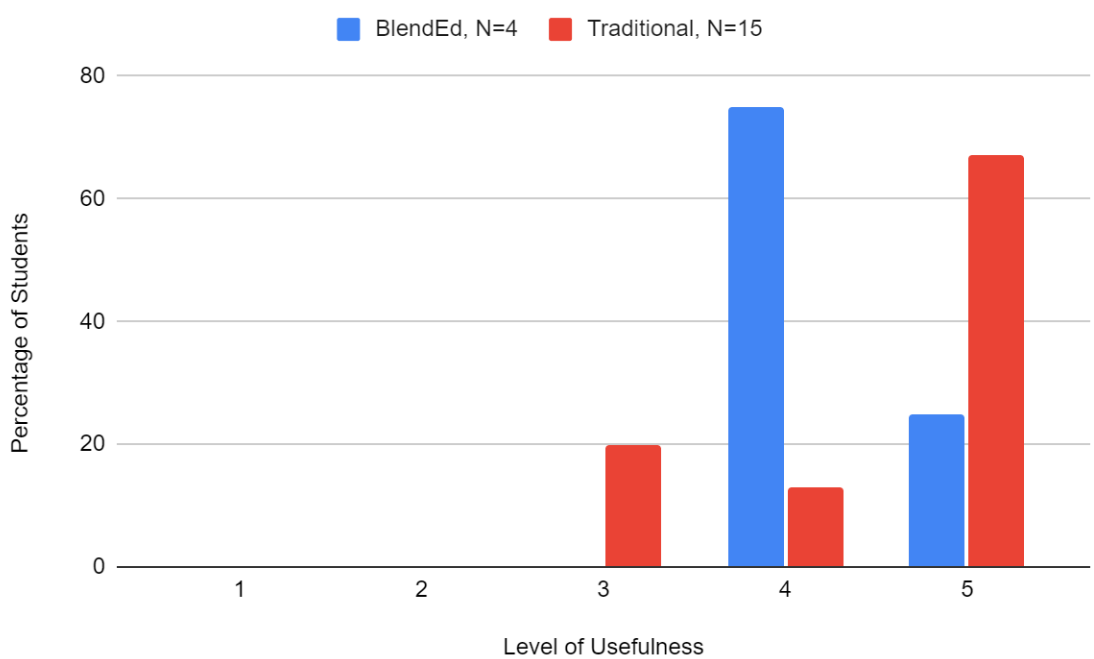

Figure 4. Student reported rating of the usefulness of #2 Pull-Back Cars Lab for growing student understanding of acceleration.

When comparing #1 Distance-Time Graphs Gizmo and #2 Pull-Back Cars Lab, overall student engagement appears to be slightly higher for the traditional, hands-on lab than for the online simulation, as shown in Figure 5. This seems to fit my personal observations as well, when observing students participating in both activities. I was able to observe both the online simulation and the traditional, hands-on lab for my traditional classes, and while most students were engaged with the work most of the time for both activities, it was clear to me from a subjective standpoint that students were more emotionally invested while completing the traditional, hands-on lab. They were able to discuss their results with each other during #2 Pull-Back Cars Lab, but did not engage in discussion during #1 Position-Time Graphs Gizmo, which is why I think they reported higher engagement scores in the survey. For my BlendEd students, I was unable to directly observe them completing #1 Position-Time Graphs Gizmo, but in the survey, my BlendEd students reported significantly higher behavioral engagement during the traditional, hands-on lab, but lower cognitive engagement.

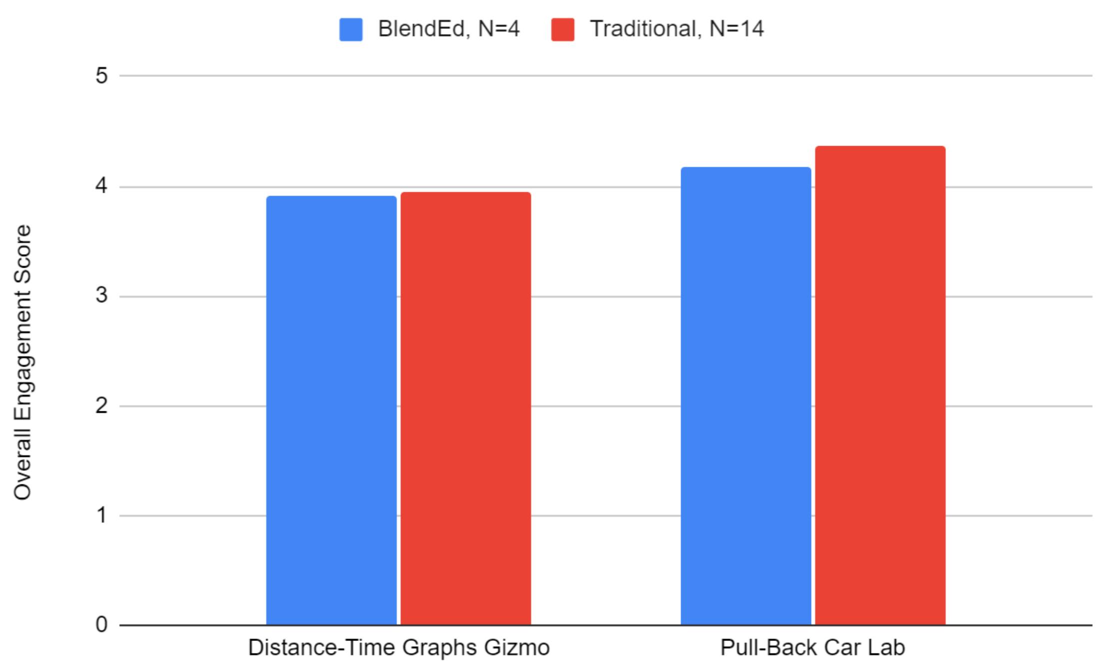

Figure 5. Student-rated overall engagement between #1 Distance-Time Graphs Gizmo and #2 Pull-Back Car Lab.

In order to determine how the level of engagement affected student understanding of the concepts, I picked a few questions on the summative assessment that addressed the key concepts learned in each formative assessment: I picked three questions on the summative assessment that addressed the relationship between position, time, and velocity, and three questions that addressed acceleration. I collected data for how many students got each question correct and incorrect, and calculated an average accuracy for the BlendEd class and the Traditional class. This data is summarized in Table 4 and Table 5, which show the results for the questions about the relationship between position, time, and velocity and for the questions about acceleration, respectively.

Table 4. Relative student understanding of the relationship between position, time, and velocity as determined by the accuracy of three questions in the Unit 1 summative assessment.

	Question 5		Question 19		Question 20		Total	Accuracy
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect		
BlendEd, *N*=7	7	0	5	2	4	3	16/21	0.762
Traditional, *N*=20	18	2	14	6	15	5	47/60	0.783

Table 5. Relative student understanding of the acceleration as determined by the accuracy of three questions in the Unit 1 summative assessment.

	Question 6		Question 12		Question 17		Total	Accuracy
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect		
BlendEd, *N*=7	4	3	7	0	7	0	18/21	0.86
Traditional, *N*=20	18	2	18	2	18	2	54/60	0.9

Unit 3 Momentum Data

Unit 3 was about understanding momentum. The two formative assessments chosen were #3 Pumpkin Drop (the hands-on, traditional lab) and #4 Air Track Gizmo (the online simulation). After each formative assessment, I gave students a survey in order to assess their own personal feelings of engagement during the activity on a scale of 1 to 5, 5 being very high levels of engagement throughout the activity. The survey for #3 Pumpkin Drop gave the engagement data found in Figure 6 as reported by students.

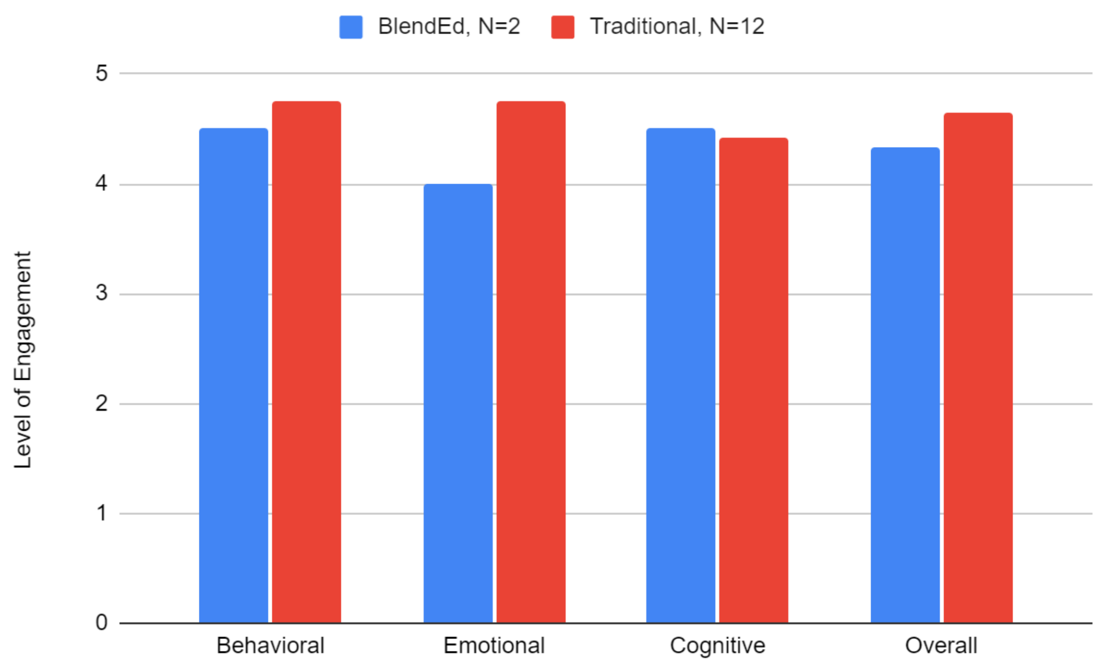

Figure 6. Levels of behavioral, emotional, and cognitive engagement for #3 Pumpkin Drop as reported by the students.

In order to assess how well students understood the content of #3 Pumpkin Drop, I chose one part of the assignment to rate the level of student understanding. I rated their ability to correctly calculate impulse on a scale of 1 to 5, 5 being they calculated impulse correctly, and 1 being did not calculate impulse at all. In this case, there were no students who received a rating of 2, 3, or 4 because they either showed their work and completed it correctly, or they didn't show their work at all. These results are summarized in Table 6.

Table 6. Number of students who scored a specific rating of understanding acceleration from the #3 Pumpkin Drop formative assessment.

	1	2	3	4	5	Average Class Rating
BlendEd, *N*=3	2	0	0	0	1	2.33
Traditional, *N*=16	7	0	0	0	9	3.25

In the survey for #3 Pumpkin Drop, I asked students to rate the usefulness of the activity in helping them grow their understanding of impulse, 5 being very helpful and 1 being not helpful at all (Figure 7).

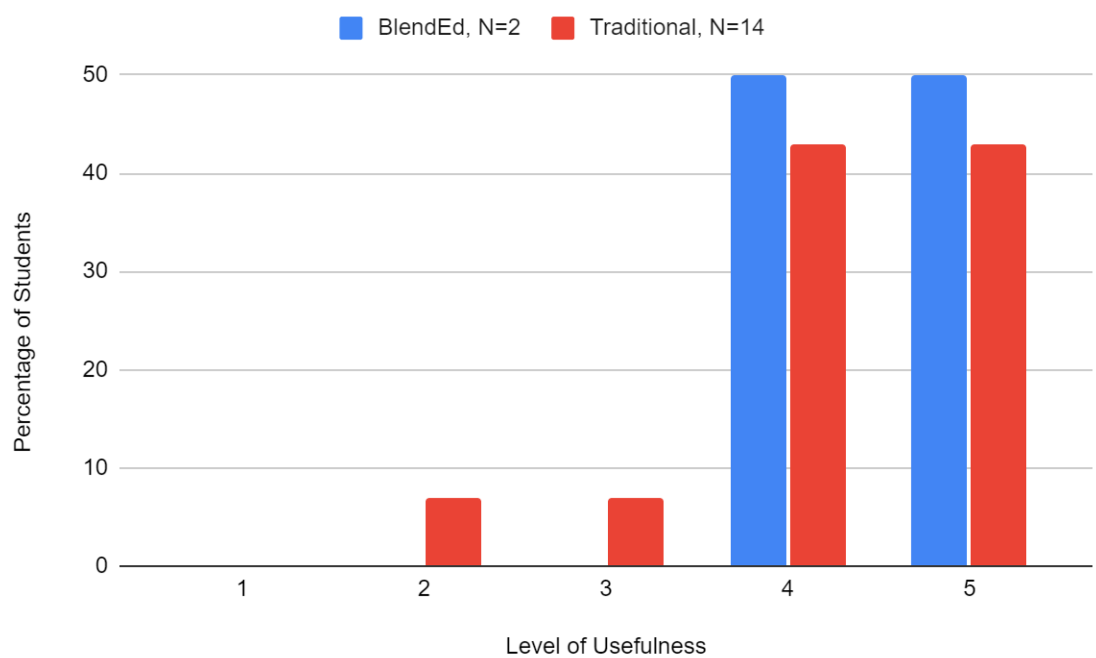

Figure 7. Student reported rating of the usefulness of #3 Pumpkin Drop for growing student understanding of impulse.

Two weeks after students completed #3 Pumpkin Drop, students completed #4 Air Track Gizmo, which was the traditional hands-on lab. Students were given the #4 Air Track Gizmo survey to assess their personal feelings of engagement during the activity on a scale of 1 to 5, 5 being very high levels of engagement throughout the activity (Figure 8).

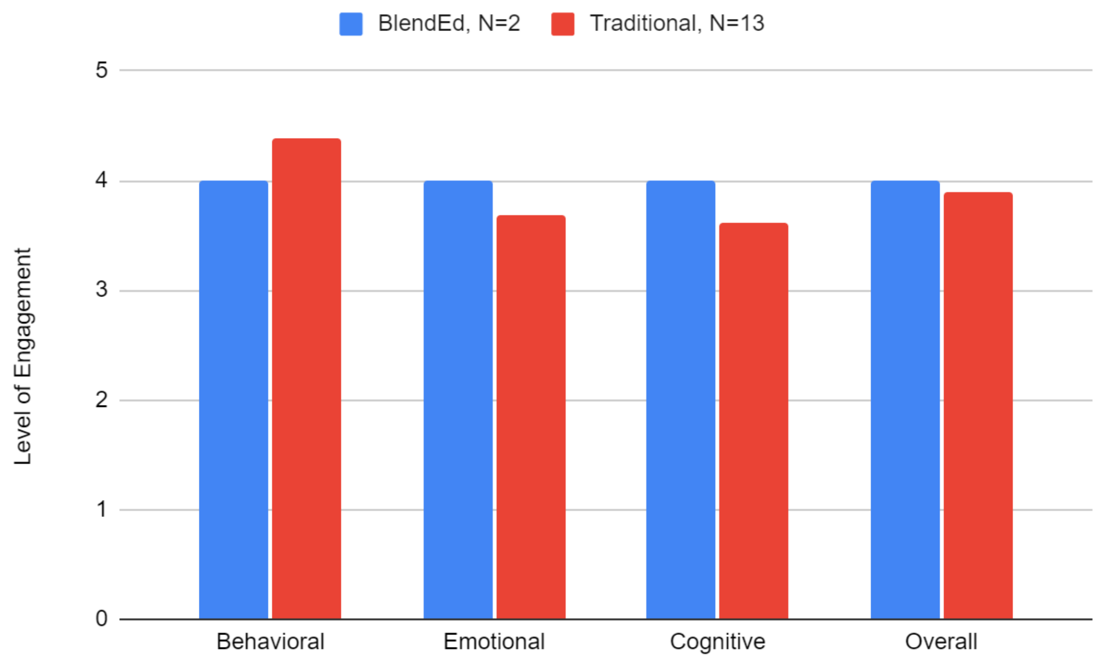

Figure 8. Levels of behavioral, emotional, and cognitive engagement for #4 Air Track Gizmo as reported by the students.

In order to assess how well students understood the content of #4 Air Track Gizmo, I chose a few specific questions from the assignment to rate the level of student understanding. I rated their understanding of the concept of conservation of momentum on a scale of 1 to 5, 5 being fully understood conservation of momentum, and 1 being did not understand conservation of momentum at all. These results are summarized in Table 7.

Table 7. Number of students who scored a specific rating of understanding conservation of momentum from the #4 Air Track Gizmo formative assessment.

	1	2	3	4	5	Average Class Rating
BlendEd, *N*=4	0	0	1	1	2	4.25
Traditional, *N*=16	0	0	1	2	13	4.75

In the survey for #4 Air Track Gizmo, I asked students to rate the usefulness of the activity in helping them grow their understanding of the conservation of momentum, 5 being very helpful and 1 being not helpful at all (Figure 9).

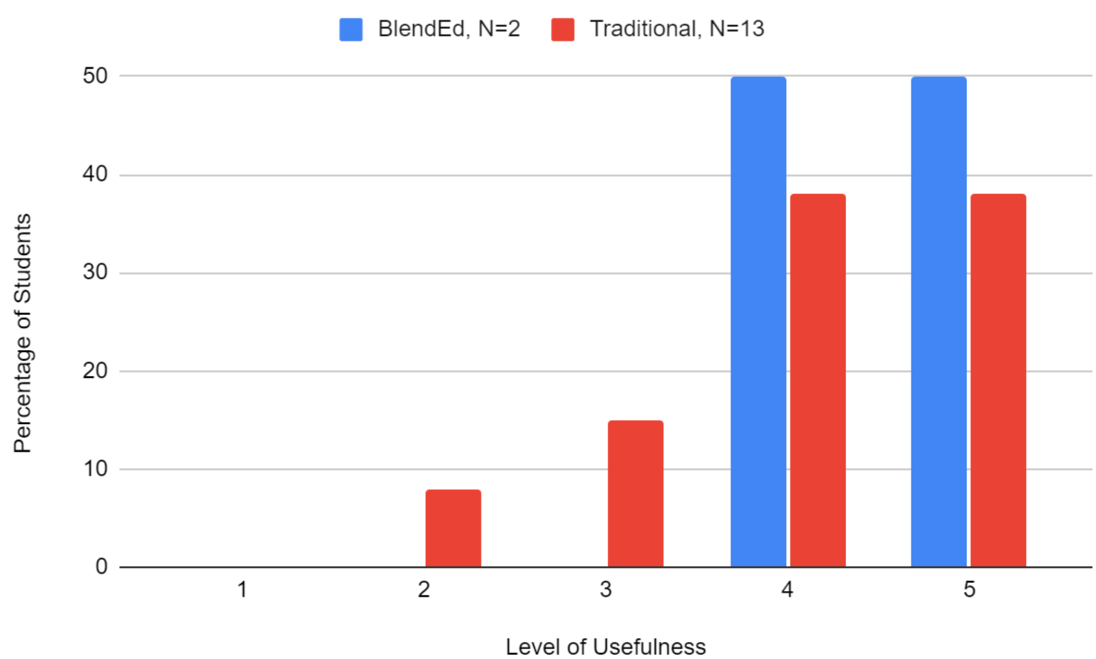

Figure 9. Student reported rating of the usefulness of #4 Air Track Gizmo for growing student understanding of the conservation of momentum.

When comparing #3 Pumpkin Drop and #4 Air Track Gizmo, overall student engagement for #3 Pumpkin Drop appears to be higher for both my BlendEd students and traditional students, as shown in Figure 10. This is not surprising since the emotional and cognitive engagement scores were significantly higher for #3 Pumpkin Drop. Unfortunately, due to a school-wide quarantine that took place during much of Unit 3, I was unable to physically observe either my BlendEd or traditional students as they completed #4 Air Track Gizmo, and for part of #3 Pumpkin Drop, so I do not have any observational data to add to the engagement analysis.

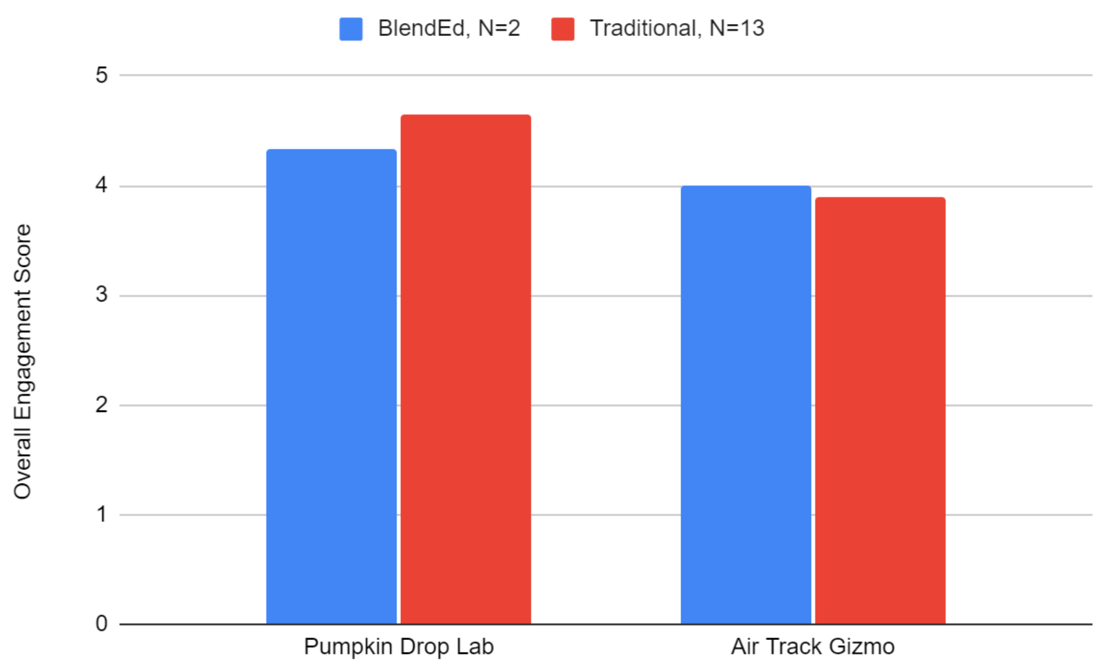

Figure 10. Student-rated overall engagement between #3 Pumpkin Drop and #4 Air Track Gizmo.

In order to determine how the level of engagement affected student understanding of the concepts, I picked a few questions on the summative assessment that addressed the key concepts learned in each formative assessment: I picked three questions on the summative assessment that addressed impulse, and three questions that addressed the conservation of momentum. I collected data for how many students got each question correct and incorrect, and calculated an average accuracy for the BlendEd class and the

Traditional class. This data is summarized in Table 8 and Table 9, which show the results for the questions about impulse and for the questions about conservation of momentum, respectively.

Table 8. Relative student understanding of impulse as determined by the accuracy of three questions in the Unit 3 summative assessment.

	Question 15		Question 17		Question 20		Total	Accuracy
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect		
BlendEd, *N*=4	4	0	2	2	3	1	9/12	0.75
Traditional, *N*=21	19	2	17	4	18	3	54/63	0.86

Table 9. Relative student understanding of conservation of momentum as determined by the accuracy of three questions in the Unit 3 summative assessment.

	Question 8		Question 13		Question 14		Total	Accuracy
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect		
BlendEd, *N*=4	3	1	0	4	2	2	5/12	0.42
Traditional, *N*=21	20	1	12	9	10	11	42/63	0.67

Comparison and Synthesis of Data

When making direct comparisons between the data sets above, there are some immediate trends that can be seen. For example, in both Unit 1 and Unit 3, students reported higher overall levels of engagement for the traditional, hands-on lab when compared to the online simulation. While the engagement scores were still relatively high for the online simulations overall, the online simulations both scored lowest in the emotional engagement category. Additionally, the traditional students seemed to have higher levels of engagement in the hands-on, traditional labs than the BlendEd students. However, when comparing overall engagement for the online simulations, the BlendEd students and traditional students reported very similar levels.

Another interesting trend is that both classes scored lower on the summative assessment on the questions with content related to the material learned during the online simulations. In the Unit 1 summative assessment, both the BlendEd students and traditional students scored lower on the questions related to the relationship between position, time, and velocity, which was the content learned during #1 Position-Time Graphs Gizmo. Similarly, on the Unit 3 summative assessment, both the BlendEd students and traditional students scored significantly lower on the questions related to the conservation of momentum, which was the content learned in #4 Air Track Gizmo.

In contrast to the summative assessment findings, I found that students understood the content better from the online simulations *in the moment* compared to understanding the content from the traditional hands-on labs *in the moment*. When comparing the overall understanding for the formative assessments, students scored higher on the online simulation formative assessments than the hands-on formative assessments. This seems to contradict the summative assessment results. I'm not entirely sure why this would happen, but I can hypothesize: these trends suggest that online simulations might be best helping students learn certain, basic concepts, but the hands-on labs help students retain their knowledge and recall it more easily when the summative assessment occurs later.

Qualitative Data for BlendEd Students

One of my focus questions for this study was to determine how the personal situations of the BlendEd students influenced their engagement and learning. To answer this question, it was most helpful to look at the survey responses of the BlendEd students for the Physics Intro survey and the Exit Survey, and compare their responses to their engagement scores and summative assessment scores. Since the BlendEd class was so small, I looked at each student's situation and compared their responses to their overall engagement and academic standing during these two units. Only five of my seven BlendEd students fully participated during these two units, so I only looked at the responses of those five. To protect student privacy I will call them Student A, B, C, D, and E, respectively, with their initials in parentheses.

Student A (C.A.) reported that he was taking this course because he wanted to "get used to taking hard classes online for college". He had never taken an online class before this one, and when asked about how he felt about online learning at the beginning of the COVID-19 pandemic in the previous school year, he said he "struggled with not being able to have the right mindset as if [he] were in class". He also reported that he learns best by seeing examples and how to do things with a visual, and the science lesson he remembers best from a previous science class is making model rockets. Based on these responses, Student A very clearly needs hands-on and visual learning tools to help him most. His responses to the exit survey seem to match my conclusion as well. He was asked what activities in the BlendEd class helped him learn best, and he said In-Person Labs, In-Person Lecture, Peer-to-Peer Discussion, and Class Discussion. He reported lower levels of overall engagement for the online simulations compared to the traditional labs, and scored higher on the questions related to the content of the traditional labs on the summative assessment.

Student B (E.E.) said that he chose to take BlendEd Physics because “I work better online and I just prefer to be by myself when working”. He reported having taken three other online classes before this one. When asked about how online school went for him last year, he said, “Some of it was annoying because some teachers were really bad with using canvas and letting people know what was due and next. Other teachers did it very well like my Digital Media teacher, because the class was already basically online.” Similar to Student A, Student B reported liking videos and examples to help him understand the content better, and learning rhymes helped him remember chemical bonds during a previous chemistry class. Interestingly, Student B said that both the Online Simulations and In-Person Labs helped him learn best. He reported slightly higher levels of engagement for the traditional labs, but still reported high engagement for the online simulations. When looking at his summative assessment scores, he scored the same on both the content related to the traditional labs and the content related to the online simulations, for both summative assessments.

Student C (L.M.) was an interesting case. During the first quarter of the school year (when Unit 1 occurred) she showed up and fully participated in class every time, did well on the assessment, and consequently received an A letter grade for the class. However, during quarter 2 (when Unit 3 happened) she essentially disappeared and I didn’t hear from her at all that quarter. Because of this, I can really only look at data for the Unit 1 assessments for her. In the intro survey, she said, “I usually struggle with my sleep schedule/feeling awake in the morning. I am late to school a lot and when I get there on time it feels almost impossible to not fall asleep and my work suffers. So this year I tried to account for that by making my morning classes work better with my schedule." She had taken six other online classes before the BlendEd Physics class, and she had a lot to say about her experiences: "[I liked that] I could take general requirements online and it would give me more time in school to take classes I'm interested in. Yet, I found that I usually didn't prioritize those classes enough so I had to finish the courses right before the deadline… Most of my teachers either posted videos that I could speed through or relied solely on online instructions (PowerPoints, assignments, etc), which made it so that I could focus better and not have to sit through long, unnecessary lectures… I also feel as though I remember and understand some of the information better because I had to think through it and connect it to relevant topics by myself without a teacher doing it for me." When asked how she learns best, she said, "Really just whenever I'm actually interested in the subject and have to recall/apply the information." When she was asked about a time when she learned something that stuck with her for a long time, she referred to the life cycle of a frog she learned in Second Grade: "We were able to watch our frogs grow from tadpoles to adults, and could see the life cycle for ourselves. I believe it sticks out in my mind because it became part of my everyday life and I had a reason to want to learn about it." From all of these responses, it is clear that she learns best when she feels like there is a reason to learn about the topic that directly applies to her, but the method of instruction doesn't really matter as much. She said that the online simulations were the most engaging to her because, "I was having to figure everything out on my own without the help of a teacher or peer... The in person labs were fun and comparable to the Gizmos, but it was hard to connect them to what I was learning. Whereas the Gizmos directly connected to the topic and you could repeat different things to see how they connected to each other." Interestingly, in the surveys, she actually reported higher levels of engagement for the traditional lab compared to the online simulation. Looking at her Unit 1 summative assessment scores, she did equally well on the questions for both the online simulation content and the traditional lab content.

Student D (S.O.) seemed to struggle with getting things done. He only completed one formative assessment (#2 Pull-Back Cars Lab), and only completed the Unit 1 Summative assessment. In the Intro Survey, he said, "I wanted to take physics, but I also needed more time to do homework because my schedule is super busy, so I decided it was a good way to balance the two." He said that he had taken two other online classes before the BlendEd Physics class, and when asked about them, he said, "I didn't like the zoom meetings, what worked for me was being able to work at my own pace, while still having a schedule to keep to." Also in the Intro survey, he reported that he likes "Hands on experiences or learning about real life examples and how they work" and he remembered an activity where he "designed a bridge to hold a specific amount of weight. I loved how it was a hands on (on computer sim) experience, I learned how to calculate the forces of trusses, and how to build a cost effective bridge." From this response, it seems that online simulations and hands-on traditional labs would work well for him, but he did not take the Exit Survey, so I don't have evidence to support that assumption.

However, he did do the survey for #2 Pull-Back Cars Lab and reported very high engagement. Additionally, on the Unit 1 summative assessment, he did equally well on both types of content questions.

Student E (K.S.) also struggled to get things turned in, and she said in the Intro Survey "I really needed the credit. I'm in BlendEd so it gives me an opportunity to sleep in since I normally work late." She had been in a whopping eight online classes before taking BlendEd from me. She said, "I really enjoyed that my teachers were more lenient when it came to late work since I do work a lot and it helps knowing I won't be failing just because I turn most of my assignments late. I disliked the inability to be in a classroom because I am the type to ask a lot of questions and I do better when I can ask them on the spot since I tend to lose interest quickly or simply just forget." When asked about what helps her learn best, she said, "Demonstrations and interacting along with a interesting lecture. Over all for me I'm the type of person to learn best when doing something as a class". She also said that the labs she had done in past science classes stuck with her most. Unfortunately, she did not take the Exit Survey so I don't know for sure which activities in the BlendEd class worked best for her, but she reported slightly higher engagement levels for the Unit 1 traditional lab than for the Unit 1 online simulation, though she gave high engagement scores for both. She did equally well on the questions related to both content topics on the Unit 1 summative assessment. Based on the informal conversations I had with her and the limited survey responses, I would suspect that she would learn best in a more traditional class, but because of her personal situation, she chose to do BlendEd just to make sure she got the credit.

LMS Behavioral Data

The learning management system that I used this school year is called Canvas. Canvas collects user data that includes page views and “participation” activity. In this case, Canvas only marks participation when a student completed an assignment through Canvas, or contributes to a discussion. Unfortunately, because my daily homework assignments are through a secondary website, the participation data that Canvas collected in mostly worthless to me in terms of this research and thus is not provided in this paper.

However, the page view data was more helpful. It tracks how many times a student views a different page on the class modules, which does include the homework assignments as well as the lesson content and other assignments. This data is shown in Figure 11 and includes the weekly total page views for each student over the course of the first semester. I should note that in order to help protect the privacy of my students, I used only their initials to identify them in Figure 11. Unit 1 occurred between August 24, 2020 and September 20, 2020, and Unit 3 occurred between October 29, 2020 and November 19, 2020. It is pretty clear that there was a significant decrease in page views during the time period of Unit 3 compared to Unit 1. Since this data is in lieu of the engagement data that would be related to attendance for traditional students, this shows a relatively lower level of behavioral engagement during Unit 3 compared to Unit 1.

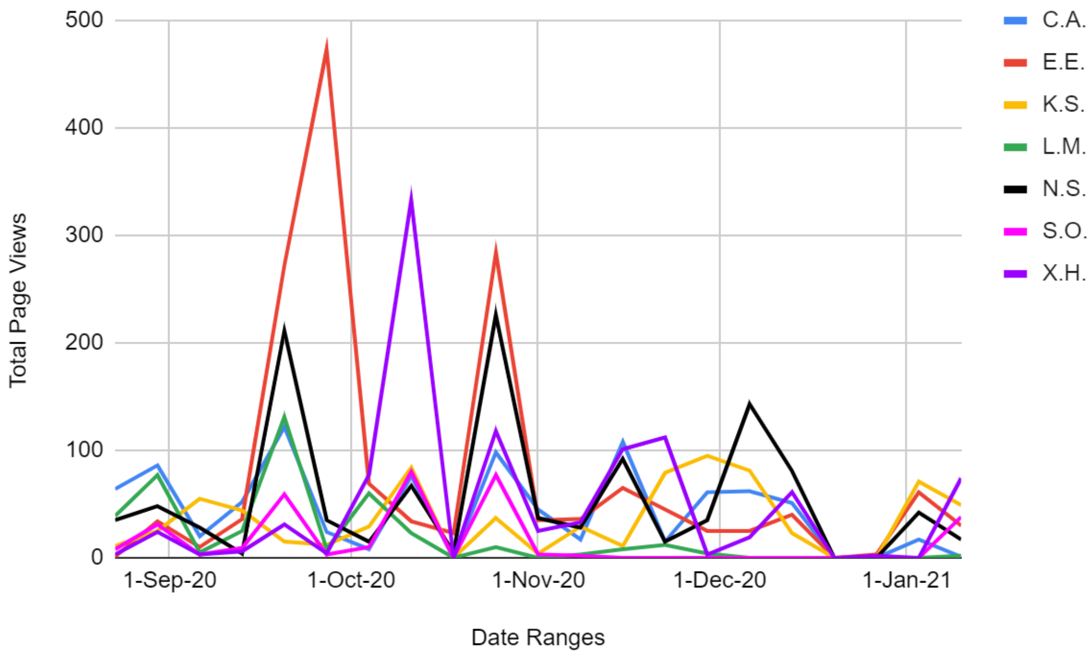

Figure 11. Total LMS-recorded weekly page views for BlendEd students.

Finalized Claims to Focus Questions

The first focus questions was, "How do hands-on, traditional labs compare to online lab simulations in fostering high student engagement in a traditional physics class and a BlendEd physics course?" Based on the evidence presented above, I claim that hands-on traditional labs foster higher levels of student engagement than online lab simulations. Also, traditional students report higher engagement in those traditional labs than the BlendEd students.

The second focus question was, "How do hands-on, traditional labs compare to online lab simulations in fostering high academic achievement in a traditional physics class and a BlendEd physics course?" Based on the evidence presented above, I claim that the hands-on, traditional labs help students learn content better with longer retention of knowledge than the online lab simulations do, thus those hands-on labs foster higher academic achievement. Though, as stated previously, the online simulations seem to help students learn content in the moment, even if they are less likely to recall that knowledge later.

The third focus question was, “How do the personal situations of students in the BlendEd Physics course affect student engagement and academic achievement?” There isn’t a concise answer to this question, but based on the experiences I’ve had this first year teaching the class, I would say that there is a specific type of learner that would thrive most in this type of course: someone who is comfortable spending a lot of time learning on their own, and who doesn’t necessarily need hands-on activities to learn the content. Student B and Student C seemed to learn the content best because they were both able to work well independently and found the online simulations just as engaging as the traditional labs.

The Influence of COVID-19

A big part in understanding the data presented in this paper is the recognition that this study took place in the middle of the COVID-19 pandemic. This added a host of other factors that affected the overall success and learning of my students. For example, our school had a substantial influx of COVID-19 cases and quarantines in our school as the school year progressed, which meant that between the times when Unit 1 and Unit 3 occurred, the number of students required to quarantine (and therefore miss school) increased dramatically. In fact, the vast majority of Unit 3 took place online for all of my students because we had a school-wide quarantine for all of November. This meant that students completed #4 Air Track Gizmo and the student worksheet part of #3 Pumpkin Drop at home on computers. While I did my best to teach the content for Unit 3 over Zoom, it is hard for me to say definitively whether or not the drop in understanding of concepts in Unit 3 was because of the different types of formative assessments. In fact, when comparing the summative assessment data for Unit 1 and Unit 3, there was a very clear decrease in average understanding during Unit 3.

Additionally, because the BlendEd Physics course was brand new this year, the recruitment for the class happened right before lockdown began back in March 2020. Because of the timing, only seven students signed up for the course, and only four or five students consistently participated in the class assignments and surveys. This created a substantial lack of data from the BlendEd course, and I simply do not have enough data to say one way or the other if the conclusions I came to are completely valid.

CLAIM, EVIDENCE, AND REASONING

At the conclusion of this research, I have found that higher student engagement generally improves academic achievement, and this is true for both BlendEd physics students and traditional physics students. However, because of the small sample sizes during this research period, I would suggest that further study is required to make a truly definitive correlation between engagement and achievement. Although the data collected wasn't decisive, it was enough to give me information about the types of students who take BlendEd physics and certainly helps me make plans for future BlendEd courses. These findings are explained in more detail below.

Claims from the Study

The focus of this study was to determine how student engagement affects academic achievement in both BlendEd Physics and a traditional physics course. After collecting data from surveys, formative assessments, summative assessments, and the LMS Canvas, I have come to a few conclusions.

First, students reported higher levels of engagement for traditional, hands-on labs compared to online simulations on average, and this is true for both the BlendEd and traditional students. Additionally, students on average scored higher on the summative assessment questions that were related to the content learned during the traditional, hands-on labs. Based on these two findings, I have come to the conclusion that higher student engagement increases overall academic achievement, and on average, the traditional, hands-on labs seem to increase overall engagement. Therefore, I would conclude that in order for students to have high academic achievement in a high school physics class, whether traditional or a BlendEd course, it is best practice to include traditional, hands-on labs whenever possible.

Second, part of this study was to help me understand why students choose to take a BlendEd Physics course and establish how students can be most successful in the course. After compiling the personal experiences of my BlendEd students and comparing them with the engagement and content knowledge data, I have come to the conclusion that the students who are most successful in the course already have the ability to work independently and can work hard to learn something on their own. Additionally, while those successful students were most engaged with traditional, hands-on labs, they also felt highly engaged when using an online simulation. Students that feel they learn best with hands-on activities and in-person lessons are less likely to learn content sufficiently in a BlendEd Physics course.

Looking back at the other researchers that I referenced in my conceptual framework, these results generally match the results of their studies. For example, Zupke compared assessment scores and student attitude (engagement) toward interactive assessments and found that those interactive assessments increased overall achievement. In the case of Zupke's study, they specifically found a positive correlation between the use of technology and student engagement, so it would be interesting to do a follow-up study that compares student engagement for a typical formative assessment (like a generic worksheet or homework assignment) and compare that to overall engagement for a Gizmo. I would guess that the online simulation would definitely have higher levels of engagement, given that my students reported high levels of engagement for the Gizmos, even if they weren't as high as the hands-on, traditional labs. Additionally, Beer et al. (2010) found that students scored higher on assessments when they interacted more with the LMS. This is also consistent with my findings. The BlendEd students who had more page views on Canvas did better on the assessments than the students who had fewer page views. Holmes had a similar result: the more often students engaged with the online platform, the higher their academic achievement was based on formative assessments.

Value of the Study and Consideration for Future Research

As I mentioned at the beginning of this paper, the BlendEd courses being offered during the 2020-2021 school year at Copper Hills High School were "test run" courses. A substantial part of why I wanted student engagement in a BlendEd course to be the focus of my action research project was to learn about the students taking these classes and how best to help them be successful so that I can improve my teaching practices for this brand new class. Additionally, I wanted to be able to bring this information back to my administrative team and my BlendEd-teaching coworkers to help them in their progress of improving this alternative class experience. This study showed me that there are some trends between the academic characteristics of students who choose to take a BlendEd course and whether or not they will be successful in being engaged and learning the content.

However, despite the trends that I found with the data I collected, I recognize that this study would not stand up against other studies with substantially more data. My sample size was quite small given what data I wanted to collect and what relationships I wanted to find within that data. Over the course of this study, I had a lot of students who ended up only doing a few of the surveys instead of all of them, and/or not completing all of the formative and summative assessments, for various reasons. This was especially problematic among the BlendEd students, because I started out with only seven students to begin with, and only two or three students completed the final few surveys and assessments. Any statistician would say that a sample size of three is not sufficient when trying to establish trends, and I would absolutely agree.

Seeing as this study had an obvious sample size problem, if I were to continue this research, I would want to start with a larger BlendEd Physics class size. Of course, how many students sign up for the class is a bit beyond my control, but I think that if I had been able to advertise for the class more, we would have had more kids sign up for it. (As I mentioned earlier, the lack of advertisement time can be directly traced back to the timing of when schools shut down because of the COVID-19 pandemic.) Additionally, I would want to increase my sample size for the traditional students as well, because an average of 14 is not a statistically significant sample size either, even if it is better than three. To accomplish this, I would collect data from two traditional physics classes instead of just one.

In addition to increasing sample sizes, I would want to evaluate more units of instruction. While there did seem to be some trends showing up with just the two units, I would want to add at least two more units of instruction to my data sets to make sure that those trends were statistically significant.

Impact of Action Research on Author

Going into the 2020-2021 school year, I had some ideas about how this new BlendEd Physics course would go. After talking to my colleagues about the goals of the course and how it would be structured, they expressed some concerns about whether or not the BlendEd students would get as valuable of a learning experience with this class as they would in a more traditional physics class, and I have to admit that their concerns belonged to me as well. There were two general concerns that we had: 1) based on our past experiences, most students are best engaged during class discussions and hands-on activities, and the BlendEd Physics course eliminates a lot of that by its very nature; and 2) not all of the students who end up signing up to take the BlendEd course would work well independently, and therefore would struggle to learn content that they would otherwise learn well in a traditional class.

After completing my action research over the course of the school year, I would say we were right to have those concerns. The data presented in this study confirms that the traditional, hands-on labs do engage students more and help them learn and remember content better, so having a class where those hands-on activities are not the focus makes learning the content more challenging. While online lab simulations are perhaps more engaging than alternative online resources, they are not an adequate replacement for those hands-on experiences.

Our second concern, regarding which students take the BlendEd class and how well they learn, was also validated by the evidence collected in the study. Students need to already have the skills to work well independently. Some of the BlendEd students who responded to Exit Survey felt this way, too. For example, one student wrote, “I think that blended physics is better but only if I keep up to date with every assignment and due date. But this is a good class to take only if you have a job and you aren’t able to come into class”. This confirms for me that this class can be an adequate replacement for a traditional physics course if the student has the need for an unconventional solution and has the skills to work consistently and is intrinsically motivated. Another student summed up my thoughts pretty well. She wrote, “I found that taking a BlendEd class to be helpful alongside my in-person traditional classes. I don't necessarily prefer it to a traditional class, because they both have their pros and cons. I find that through the BlendEd class it's easier to learn at a pace I'm comfortable with… I like that I have to challenge myself and I find that I understand topics more in-depth because I'm figuring things out on my own... Though, it's harder for me to stay up to pace and often I forget about the class. When I don't have to go into class every day, it's harder to stay accountable for doing the assignments.”

Overall, I can say that this first year of offering a BlendEd Physics course was successful in that I learned a lot about what works and what doesn’t, and I now have the opportunity to take this information to my administrative team and the other BlendEd teachers so that we can work together to make the class better in the future. I plan to make the in-person lab days more frequent and use fewer simulations. Additionally, I would like to have us come up with a “vetting” process to make sure the students who are taking the class have the skills to succeed in it. I think it would also be beneficial to have weekly discussion forums over the LMS for the students who do need more interpersonal interaction. While it may not completely replace in-person classroom discussions or lectures, after my time in the MSSE program, I have learned that it is possible to have valuable online discussions. Lastly, I would say that while the BlendEd Physics class is certainly a very different learning experience for students, with more research and a little metaphorical elbow grease, I believe it can become just as engaging and host just as much student success as a traditional physics class.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD 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:
Application Number:
****

DATE of SUBMISSION: August 11th, 2020

Address each section – do not leave any section blank.

I. INVESTIGATOR:

Name: **Marissa Beck**
Home Mailing Address: **8638 N Cottonwood Alley, Eagle Mountain, UT, 84005**
Telephone Number: **(206) 972-0006**
E-Mail Address: **risa.d.mannard@gmail.com**
DATE TRAINING COMPLETED: **February 15th, 2020** *[Required training: CITI training; see website for link]*

Investigator Signature ______________________

Name of Project Advisor: **Marcie Reuer**
E-Mail Address of Project Advisor: **marcie.reuer@ecat1.montana.edu**

II. TITLE OF RESEARCH PROJECT: **Student Engagement in Traditional and Blended Physics Courses**

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a survey/questionnaire, provide a copy).
My data collection methods with include self-report student surveys (attached), direct instructor observations, Learning Management System (LMS) behavioral data, formative assessment data, and summative assessment data. The student surveys will include self-reported feelings of engagement during various activities, and a rating of how well each activity helped students understand the scientific concepts being taught. Direct instructor observations will include observations of student behavior during the activities (i.e. "on-task" and "off-task" behaviors). The LMS I will be using is Canvas, and I will collect student data from Canvas including number of logins, time spent on specific assignments, number of clicks, etc. Formative assessment data will be in the form of grades for homework quizzes, and summative assessment data will be based on correct/incorrect answers for a multiple-choice test.

IV. RISKS AND INCONVENIENCES TO SUBJECTS (**do not answer 'None'**):
There will be a total of 8 surveys given to students over the course of the research period. The first and last surveys will likely take about 30 minutes each. The six intermediate surveys will take approximately 5 minutes each. All of the surveys will need to be completed outside of class time, so it could be considered a significant inconvenience of time for some students. The surveys will record student names and responses. The first survey will ask for some personal information from students, specifically level of academic support at home, relative accessibility of a computer and internet, and personal reasons for choosing to take a blended learning class. The surveys will all be digital, and will be stored in my school Gmail account.

APPENDIX B

PHYSICS INTRO SURVEY

Physics Entry Survey

Please complete this survey as honestly as possible with as much detail as possible. I, Mrs. Beck, will be the only person to see your name with your responses. When I share data from this survey in my capstone paper, I will not use any names. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What is your name?

   ____

2. What would you like me to know about you? This could be literally anything--a personal struggle that you think I should know about, or that you're part of 10 clubs, or what your Hogwarts House is. Help me get to know you!

3. Are you in BlendEd Physics, or regular Physics?

   Mark only one oval.

   ◯ BlendEd Physics

   ◯ Regular Physics

4. If you are taking a BlendEd course (either physics or another BlendEd class in the school), please explain why you chose to take it. Please be super honest and detailed, and don't be afraid to talk about your personal situation and feelings. i.e. Is it because you have to work? Do you find it hard to concentrate in a class with a lot of students?

APPENDIX B CONTINUED

5. NOT including the online learning that happened at the end of last year, how many online or blended learning classes have you taken before? (If you are in BlendEd classes this year, include those.)

Mark only one oval.

- ◯ I have never taken an online or Blended Learning class before
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ More than 10

6. If you have taken a BlendEd or online course before, INCLUDING the online learning that we did at the end of last year, what were things that you liked/disliked about it? What worked for you and what didn't? Please be brutally honest and detailed.

7. Please open a new tab. In the Google search bar, search for "VARK questionnaire for younger people", and click on the first link that pops up. Complete the questionnaire. When you are done, select which kind of learner you are. DO NOT CLOSE THE TAB YET.

Mark only one oval.

- ◯ Multimodal
- ◯ Visual
- ◯ Aural
- ◯ Read/Write
- ◯ Kinesthetic

8. What was your Visual score, according to the VARK questionnaire? Type in the number.

9. What was your Aural score, according to the VARK questionnaire? Type in the number.

10. What was your Read/Write score, according to the VARK questionnaire? Type in the number.

APPENDIX B CONTINUED

11. What was your Kinesthetic score, according to the VARK questionnaire? Type in the number.

12. When it comes to school, how do you think you learn the best? Give some examples. (This doesn't necessarily mean that it is the easiest for you, but what truly helps you learn and understand new content?)

13. Try to think about an activity you have done in a science class in the past that really stuck with you (could be a homework assignment, project, lab, field trip, etc.). What was the activity? Why does it stick out in your mind? Do you remember a science concept that you learned because of this activity? Try to be as detailed and specific as possible.

14. How would you rate the availability of computer and internet access at home, on a scale of 1 to 5?

Mark only one oval.

	1	2	3	4	5	
I never have access to a computer or the internet at home	◯	◯	◯	◯	◯	I have access to a computer and the internet whenever I need it

15. How would you rate the level of support that you get at home when it comes to succeeding academically, on a scale of 1 to 5? For example, are you asked what you are learning in school consistently? Does someone offer to help you with homework or projects when you need it? Do you feel like you can talk to someone at home about your concerns about school? (Don't try to spare anyone's feelings here. Be honest with yourself.)

Mark only one oval.

	1	2	3	4	5	
I have no support at home.	◯	◯	◯	◯	◯	I have people at home that thoroughly support me.

16. When it comes to academics, how independent do you feel? i.e. Does someone need to remind you to do your work constantly? When you are stuck on a problem, can you figure it out by yourself using resources available to you?

Mark only one oval.

	1	2	3	4	5	
I do not feel independent at all.	◯	◯	◯	◯	◯	I feel completely independent.

APPENDIX C

#1 DISTANCE-TIME GRAPHS GIZMO: ACTIVITY SURVEY

#1 Distance-Time Graphs Gizmo: Activity Survey

Please complete this survey with BRUTAL HONESTY (don't spare anyone's feelings) with as much detail as possible. I, Mrs. Beck, will be the only person to see your name with your responses. When I share data from this survey in my capstone paper, I will not use any names. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What is your name?

____

2. Are you in BlendEd physics, or regular physics?

Mark only one oval.

( ) BlendEd Physics
( ) Regular Physics

3. How would you rate your level of BEHAVIORAL engagement during this activity? In other words, were you on task the majority (more than 80%) of the time? (Think about time spent on phone, chatting about unrelated things, bored/staring off into space, etc.)

Mark only one oval.

	1	2	3	4	5	
On task less than 20% of the time	( )	( )	( )	( )	( )	On task more than 80% of the time

4. How would you rate your level of EMOTIONAL engagement during this activity? In other words, was it a positive learning experience that interested you in science?

Mark only one oval.

	1	2	3	4	5	
Very negative experience, low interest	( )	( )	( )	( )	( )	Very positive experience, high interest

APPENDIX C CONTINUED

5. How would you rate your level of COGNITIVE engagement during this activity? In other words, how much mental effort did you make to understand the the science concepts in the activity? Were you challenged to think critically and/or problem-solve during the activity?

   Mark only one oval.

	1	2	3	4	5	
Little to no mental effort, did not think critically	◯	◯	◯	◯	◯	A lot of mental effort, did think critically

6. OVERALL, how would you rate your engagement during this activity?

   Mark only one oval.

	1	2	3	4	5	
Little to no engagement	◯	◯	◯	◯	◯	Very engaged most of the time

7. Summarize what scientific concept(s) this activity helped you learn or understand better.

8. The purpose of this activity was to help you understand the relationship between position, time, and velocity. How would you rate the usefulness of this activity in helping you grow your understanding of this scientific concept?

   Mark only one oval.

	1	2	3	4	5	
Did not grow my understanding at all.	◯	◯	◯	◯	◯	Highly effective at growing my understanding

APPENDIX D

#2 PULL-BACK CARS LAB: ACTIVITY SURVEY

#2 Pull-Back Cars lab: Activity Survey

Please complete this survey with BRUTAL HONESTY (don't spare anyone's feelings) with as much detail as possible. I, Mrs. Beck, will be the only person to see your name with your responses. When I share data from this survey in my capstone paper, I will not use any names. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What is your name?

____

2. Are you in BlendEd physics, or regular physics?

   Mark only one oval.

   ◯ BlendEd Physics

   ◯ Regular Physics

3. How would you rate your level of BEHAVIORAL engagement during this activity? In other words, were you on task the majority (more than 80%) of the time? (Think about time spent on phone, chatting about unrelated things, bored/staring off into space, etc.)

   Mark only one oval.

	1	2	3	4	5	
On task less than 20% of the time	◯	◯	◯	◯	◯	On task more than 80% of the time

4. How would you rate your level of EMOTIONAL engagement during this activity? In other words, was it a positive learning experience that interested you in science?

   Mark only one oval.

	1	2	3	4	5	
Very negative experience, low interest	◯	◯	◯	◯	◯	Very positive experience, high interest

APPENDIX D CONTINUED

5. How would you rate your level of COGNITIVE engagement during this activity? In other words, how much mental effort did you make to understand the the science concepts in the activity? Were you challenged to think critically and/or problem-solve during the activity?

Mark only one oval.

	1	2	3	4	5	
Little to no mental effort, did not think critically	⬭	⬭	⬭	⬭	⬭	A lot of mental effort, did think critically

6. OVERALL, how would you rate your engagement during this activity?

Mark only one oval.

	1	2	3	4	5	
Little to no engagement	⬭	⬭	⬭	⬭	⬭	Very engaged most of the time

7. Summarize what scientific concept(s) this activity helped you learn or understand better.

____
____
____
____
____

8. The purpose of this activity was to help you understand acceleration. How would you rate the usefulness of this activity in helping you grow your understanding of this scientific concept?

Mark only one oval.

	1	2	3	4	5	
Did not grow my understanding at all.	⬭	⬭	⬭	⬭	⬭	Highly effective at growing my understanding

APPENDIX E

#3 PUMPKIN DROP: ACTIVITY SURVEY

#3 Pumpkin Drop: Activity Survey

Please complete this survey with BRUTAL HONESTY (don't spare anyone's feelings) with as much detail as possible. I, Mrs. Beck, will be the only person to see your name with your responses. When I share data from this survey in my capstone paper, I will not use any names.Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What is your name?

____

2. Are you in BlendEd physics, or regular physics?

   Mark only one oval.

   ◯ BlendEd Physics

   ◯ Regular Physics

3. How would you rate your level of BEHAVIORAL engagement during this activity? In other words, were you on task the majority (more than 80%) of the time? (Think about time spent on phone, chatting about unrelated things, bored/staring off into space, etc.)

   Mark only one oval.

	1	2	3	4	5	
On task less than 20% of the time	◯	◯	◯	◯	◯	On task more than 80% of the time

4. How would you rate your level of EMOTIONAL engagement during this activity? In other words, was it a positive learning experience that interested you in science?

   Mark only one oval.

	1	2	3	4	5	
Very negative experience, low interest	◯	◯	◯	◯	◯	Very positive experience, high interest

APPENDIX E CONTINUED

5. How would you rate your level of COGNITIVE engagement during this activity? In other words, how much mental effort did you make to understand the the science concepts in the activity? Were you challenged to think critically and/or problem-solve during the activity?

Mark only one oval.

	1	2	3	4	5	
Little to no mental effort, did not think critically	◯	◯	◯	◯	◯	A lot of mental effort, did think critically

6. OVERALL, how would you rate your engagement during this activity?

Mark only one oval.

	1	2	3	4	5	
Little to no engagement	◯	◯	◯	◯	◯	Very engaged most of the time

7. Summarize what scientific concept(s) this activity helped you learn or understand better.

8. The purpose of this activity was to help you understand impulse (the change of momentum). How would you rate the usefulness of this activity in helping you grow your understanding of these scientific concepts?

Mark only one oval.

	1	2	3	4	5	
Did not grow my understanding at all.	◯	◯	◯	◯	◯	Highly effective at growing my understanding

APPENDIX F

#4 AIR TRACK GIZMO: ACTIVITY SURVEY

#4 Air Track Gizmo: Activity Survey

Please complete this survey with BRUTAL HONESTY (don't spare anyone's feelings) with as much detail as possible. I, Mrs. Beck, will be the only person to see your name with your responses. When I share data from this survey in my capstone paper, I will not use any names. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What is your name?

____

2. Are you in BlendEd physics, or regular physics?

Mark only one oval.

- ⬭ BlendEd Physics
- ⬭ Regular Physics

3. How would you rate your level of BEHAVIORAL engagement during this activity? In other words, were you on task the majority (more than 80%) of the time? (Think about time spent on phone, chatting about unrelated things, bored/staring off into space, etc.)

Mark only one oval.

	1	2	3	4	5	
On task less than 20% of the time	⬭	⬭	⬭	⬭	⬭	On task more than 80% of the time

4. How would you rate your level of EMOTIONAL engagement during this activity? In other words, was it a positive learning experience that was interesting to you?

Mark only one oval.

	1	2	3	4	5	
Very negative experience, low interest	⬭	⬭	⬭	⬭	⬭	Very positive experience, high interest

APPENDIX F CONTINUED

5. How would you rate your level of COGNITIVE engagement during this activity? In other words, how much mental effort did you make to understand the the science concepts in the activity? Were you challenged to think critically and/or problem-solve during the activity?

Mark only one oval.

	1	2	3	4	5	
Little to no mental effort, did not think critically	⬭	⬭	⬭	⬭	⬭	A lot of mental effort, did think critically

6. OVERALL, how would you rate your engagement during this activity?

Mark only one oval.

	1	2	3	4	5	
Little to no engagement	⬭	⬭	⬭	⬭	⬭	Very engaged most of the time

7. Summarize what scientific concept(s) this activity helped you learn or understand better.

8. The purpose of this activity was to help you understand the difference between elastic and inelastic collisions, calculate momentum, and understand that momentum is conserved before and after a collision. How would you rate the usefulness of this activity in helping you grow your understanding of these scientific concepts?

Mark only one oval.

	1	2	3	4	5	
Did not grow my understanding at all.	⬭	⬭	⬭	⬭	⬭	Highly effective at growing my understanding

APPENDIX G

EXIT SURVEY

Exit Survey

Please complete this survey with BRUTAL HONESTY (don't spare anyone's feelings) with as much detail as possible. I, Mrs. Beck, will be the only person to see your name with your responses. When I share data from this survey in my capstone paper, I will not use any names. Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What is your name?

____

2. Are you in BlendEd Physics, or Regular Physics?

Mark only one oval.

- ( ) BlendEd Physics
- ( ) Regular Physics

3. What activities in physics do you feel have helped you learn best? Select all that apply. (These might not be the most fun or the easiest, though that could be part of it--I'm looking for what helped you learn the science content best.)

Check all that apply.

- [ ] Homework Quizzes
- [ ] Online Readings/Text
- [ ] Online Simulations (Gizmos)
- [ ] In-person Labs
- [ ] In-person lecture
- [ ] Peer-to-Peer discussions
- [ ] Videos
- [ ] White-boarding
- [ ] Class discussions
- [ ] Nearpods

Other: [ ] _______________________________

APPENDIX G CONTINUED

4. Which of the following activities in Physics do you think kept you the most BEHAVIORALLY engaged while completing them? For example, during which activities were you the least distracted by unrelated things (phones, chatting with friends, etc.)? Select all that apply.

Check all that apply.

- [ ] Homework quizzes
- [ ] Online readings/text
- [ ] Online Simulations (Gizmos)
- [ ] In-person labs
- [ ] In-person lecture
- [ ] Peer-to-peer discussions
- [ ] Videos
- [ ] White-boarding
- [ ] Class discussions
- [ ] Nearpods

Other: [ ] ______________________

5. Which of the following activities in Physics do you think kept you the most EMOTIONALLY engaged while completing them? For example, during which activities were you most interested in learning science concepts? Which activities made learning science concepts a positive learning experience? Select all that apply.

Check all that apply.

- [ ] Homework Quizzes
- [ ] Online readings/text
- [ ] Online Simulations (Gizmos)
- [ ] In-person labs
- [ ] In-person lecture
- [ ] Peer-to-peer discussions
- [ ] Videos
- [ ] White-boarding
- [ ] Class discussions
- [ ] Nearpods

Other: [ ] ______________________

APPENDIX G CONTINUED

6. Which of the following activities in Physics do you think kept you the most COGNITIVELY engaged while completing them? For example, during which activities were you putting forth the most effort to understand science concepts? Which activities challenged you to think critically about science concepts? Select all that apply.

   Check all that apply.

   - [ ] Homework Quizzes
   - [ ] Online readings/text
   - [ ] Online simulations (Gizmos)
   - [ ] In-person labs
   - [ ] In-person lectures
   - [ ] Peer-to-peer discussions
   - [ ] Videos
   - [ ] White-boarding
   - [ ] Class discussions
   - [ ] Nearpods

   Other: [ ] ______________________

7. Which SPECIFIC activities (like, a specific lab or Gizmo or discussion) were the most engaging TO YOU over the last 3 units? I know we have done a lot, but try to think of the things that stick out in your mind. Was there an activity or activities that really helped you understand a concept, or something that made you feel really involved in the learning process? Something that you will remember months or years from now? Be as specific and detailed as possible.

   ____

   ____

   ____

   ____

   ____

APPENDIX G CONTINUED

8. *FOR BLENDED STUDENTS ONLY: How would you compare your learning experience in the BlendEd class to a traditional class? Were you more or less engaged in the learning process? Academically, are you doing better or worse than you would in a traditional class? Do you still think it was a good idea for you to take the BlendEd class? Please be as honest and detailed as possible.

APPENDIX H

PULL-BACK CARS LAB

Pull-Back Cars Lab

Purpose: Use position, time, and velocity data to calculate acceleration.

Investigative Question: Do pull-back toy cars accelerate?

Lab Report:
Students will use their creativity to find a way to measure the position of a dune buggy and pull-back car over 8 seconds.
On graph paper, students should write a lab report which includes:

- The Investigative Question
- A written procedure to help you answer the investigative question
- A data table
- A graph (or graphs) of the data with position on the y-axis and time on the x-axis for both the dune buggy and the pull back car.
- A CER response to the investigative question
- All data must be reported with the appropriate metric unit
- Show all your work

Students need to answer all analysis questions.. I would recommend doing the analysis questions BEFORE doing the CER response.

Grading rubric

1	2	3
Complete the experiment and report the data Record a minimum of 6 data points	The experiment is completed; some parts, but not all, of the lab report are complete	All portions of the lab report are present and clearly stated; all analysis questions are answered
4 - above and beyond		

ANALYSIS QUESTIONS *(Show all your work.)*

1. Compare the position-time graphs of the dune buggy and the pull-back car. What do the graphs tell you about the motion of each toy?

APPENDIX H CONTINUED

2. Calculate the average velocity of the dune buggy between 0 and 8 seconds.

3. Calculate the average velocity of the pull-back car between 0 and 8 seconds.

4. What does the slope on a position-time graph represent?

5. Does the slope of the dune buggy graph change? What does this mean?

6. Does the slope of the pull-back car graph change? What does this mean?

7. Calculate the slope between the first two points on the pull-back car graph.

8. Calculate the slope between the last two points on the pull-back car graph.

9. Calculate the acceleration of the pull-back car.

10. Do you think your answer to #9 is an accurate calculation for the toy's acceleration? Why or why not?

APPENDIX I

PUMPKIN DROP HANDOUT

The 2020 Physics Pumpkin Drop

(A Day: Oct. 28th -- B Day: Oct. 29th)

Learning goals:

1. Use your understanding of momentum and impulse to design a device that can catch a pumpkin dropped from the roof of the school.
2. Calculate the total impulse experienced by your pumpkin.

Specifications:

- Your pumpkin catcher should be **1m by 1m in size or larger** so that the pumpkin droppers can hit it from the rooftop of the school.
- Bring **2 or 3 pumpkins (at least 5 lbs each)**. Your pumpkin catcher needs to be able to quickly be moved into position (1 to 2 minutes tops) and quickly removed afterwards.
    - Write your name on pumpkins with permanent marker and ask your teacher where you can store them.
- Your team can consist of up to 4 people (from any Physics class) no more. You need a MINIMUM of two people per group on drop day: someone on the roof and someone on the ground.
- Material restrictions
    - Nothing too hard to clean up. (ex: Styrofoam peanuts, jello, popcorn, etc.)
    - No Trash cans filled with water or leaves. -Too simple and the leaves are too messy.
    - No Pillows, cushions, blankets, etc. folded to make a cushion. -Too simple.
- Your catcher must not generate any dangerous projectiles, even when impacted by an approximately 15m/s (33.5 mph) pumpkin.
- Your pumpkin catcher must be ready **BEFORE** class to receive points.
- If you are partners with someone in another class, it is up to YOU to make arrangements to be there for the drop. **We will NOT write excusal notes for you**.
- Cannot be taller than 3.3m tall (approx. 10 feet).
- Nobody will be allowed within 15 feet of the catchers while pumpkins are dropping.

Grading Rubric -- Total points possible /20

Points	Qualification
5	**Completed Pumpkin Catcher** (Email your names, period, and a picture of your catcher with your whole team to your teachers by Oct 27th to get credit)
5	**Catch pumpkin without breaking**
5	**Collecting all of the data** needed in an organized way and analyzing your data thoroughly in order to calculate the impulse of the pumpkin.
5	**Calculate the impulse of your pumpkin as it hits the catcher.** Show all work.
2	Extra credit for surviving pumpkins >10 pounds.

APPENDIX I CONTINUED

Your Name:________________________________ Period:____________________
Teammate 2 Name:__________________________ Period and Teacher:______________
Teammate 3 Name:__________________________ Period and Teacher:______________
Teammate 4 Name:__________________________ Period and Teacher:______________

What is the weight of your largest surviving pumpkin? Put an ***X*** *if your pumpkin did not survive. (in lbs)* _______________

Design: draw a blueprint of your pumpkin catcher, please include as many details as you can.

Plan: Write a short paragraph explaining how your design will stop the momentum of the pumpkin as it falls. Use vocabulary words from class including momentum, impulse and force.

Data: You MUST collect time data and the mass of the pumpkin!

Calculations: use the equation $v_f = v_i + at$ to figure out the velocity of your pumpkin when it hit the pumpkin catcher. Use 9.8 m/s^2 as the acceleration (ignore air resistance). Find the total impulse of the pumpkin as it was stopped by your pumpkin catcher.

APPENDIX J

DISTANCE-TIME GRAPHS GIZMO WORKSHEET

Gizmos: Distance-Time Graphs

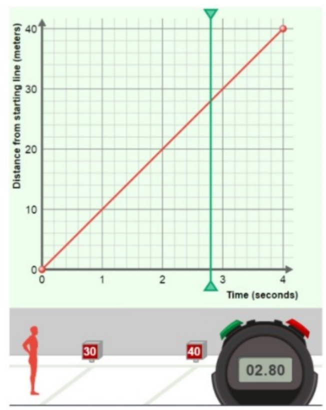
Answer all the questions below using a red font.

Prior Knowledge Questions (Do these BEFORE the Gizmo)
Max ran 50 meters in 10 seconds. Molly ran 30 meters in 5 seconds.

1. Who ran farther, Max or Molly? _______________
2. Who ran faster? Explain your reasoning.

GIZMO WARM UP

The *Distance-Time Graphs* Gizmo shows a graph and a runner on a track. You can control the motion of the runner by manipulating the graph (drag the red dots). Check that **Number of points** is 2, and that under **Runner 1** both **Show graph** and **Show animation** are turned on.



The graph should look like the one shown to the right – one point at (0, 0) and the other point at (4, 40).

1. Click the green **Start** button. What happens?

2. Click the red **Reset** button on the stopwatch. The vertical green probe on the graph allows you to see a snapshot of the runner at any point in time. Drag it back and forth. As you do, watch the runner and the stopwatch.

   a. What was the position of the runner at 1 second? ___________
   b. What are the coordinates of the point on the graph that tells you this? (___, ___)
   c. When was the runner on the 30-meter line?___________
   d. What are the coordinates of the point on the graph that tells you this? (___, ___)

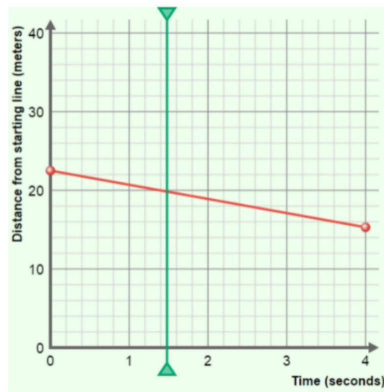
APPENDIX J CONTINUED

ACTIVITY A **Runner Position**	Get the Gizmo ready: ● Click the red **Reset** button on the stopwatch. ● Be sure the **Number of points** is 2.

In the Gizmo, run the "race" many times with a variety of different graphs. (The red points on the graph can be dragged vertically.) Pay attention to what the graph tells you about the runner.

1. If a distance-time graph contains the point (4, 15), what does that tell you about the runner? (Be specific, and answer in a complete sentence.)

2. Look at the graph to the right. Notice where the green probe is. If you could see the runner and the stopwatch at this moment, what would you see?



3. Look at the image below, from the Gizmo. What must be true about this runner's graph?

4. The point on the graph that lies on the y-axis (vertical axis) is called the **y-intercept**. What does the y-intercept tell you about the runner?

APPENDIX J CONTINUED

ACTIVITY B **Runner Direction and Speed**	Get the Gizmo ready: ● Click the red **Reset** button on the stopwatch.

Run the Gizmo several times with different types of graphs. (Remember, the red points on the graph can be dragged vertically.) Pay attention to the speed and direction of the runner.

1. Create a graph of a runner that is running forward (from left to right) in the Gizmo. Take a screenshot of the graph you create and insert it below.

   If the runner is moving from left to right in the Gizmo, how does the graph always look?

2. Click the red **Reset** button. Create a graph of a runner that is running from right to left. Take a screenshot of the graph and insert it below.

   How does the graph always look if the runner is moving from right to left in the Gizmo?

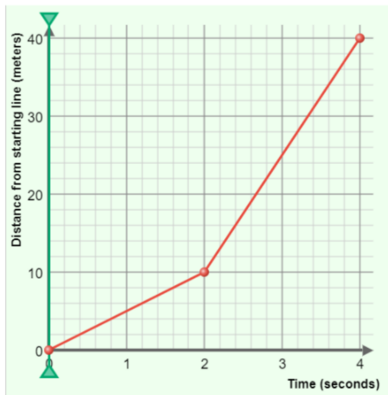
3. Change the **Number of points** to 5. Create a graph of a runner that runs left-to-right for one second, rests for two seconds, and then continues running in the same direction. Take a screenshot of the graph and insert it below.

   How does a graph show a runner at rest?

4. In general, how does a distance-time graph show you which direction the runner is moving?

5. With Number of points set to 3, create the graph shown below. Your graph should include (0, 0), (2, 10), and (4, 40). This graph will be used to complete questions 5 through 8.

APPENDIX J CONTINUED



a. Where does the runner start? ______________________
b. Where will he be after 2 seconds? _________________
c. Where will he be after 4 seconds? _________________
d. In which time interval do you think the runner will be moving most quickly? (Highlight your answer) 0 to 2 seconds 2 to 4 seconds

6. Click the **Start** button and watch the animation. What about the runner changed after 2 seconds of running?

7. **Speed** is a measure of how fast something is moving. To calculate speed, divide the distance by the time. In the Gizmo, the units of speed are meters per second (m/s).
   a. In the first 2 seconds, how far did the runner go? _________________________
   b. In this time interval, how far did the runner go each second? _______________
   c. In this time interval, what was the runner's speed? ________________________

8. Now look at the last two seconds represented on the graph.
   a. In the last 2 seconds, how far did the runner go? __________________________
   b. In this time interval, how far did the runner go each second? ________________
   c. In this time interval, what was the runner's speed?__________________________

9. Click the **Reset** button. Experiment with a variety of graphs, focusing on the speed of the runner. In general, how can you estimate the speed of the runner by looking at a graph?

APPENDIX J CONTINUED

ACTIVITY C **Two runners, Two Graphs**	Get the Gizmo ready: ● Click **Reset**. ● Under **Runner 2**, turn on **Show graph** and **Show animation**.

Experiment with the Gizmo to create each of the following results. (You can use any number of points in your graphs.) Each time you find a solution, click the camera icon next to the graph. Right click the image, and click Copy Image. Then paste the image below the appropriate situation.

1. Runner 1 wins the race.
2. Runner 2 wins the race.
3. Runner 2 catches up to and passes runner 1.
4. Runner 2 is going in the opposite direction as runner 1.
5. Each runner goes at a different speed, but both reach the finish line together.

Based on your experiments, answer the following questions.

1. How does the graph show if a runner gets a head start?
2. How does the graph show which runner is faster?
3. How does the graph show which runner wins the race?
4. How does the graph show a runner going back and forth?
5. What does it mean when the two runners' graphs cross?

APPENDIX K

AIR TRACK GIZMO WORKSHEET

Gizmos: Air Track

Answer all the questions below using a red font.

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Imagine going to a bowling alley with a bowling ball and a ping pong ball.

1. Why is a bowling ball better for knocking down pins than a ping pong ball?

2. Which do you think would knock down more pins, a bowling ball moving 10 meters per second or a bowling ball moving 10 centimeters per second?

3. What two factors seem to most affect the amount of damage that occurs in a collision?

GIZMO WARM-UP
An **air track** is a device that helps scientists study motion. Air comes out of holes in the track, allowing the gliders to move with minimal friction.

1. On the Air Track Gizmo, click **Play** to view a collision between the two gliders. What do you see?

2. Click **Reset**. The velocity (v) of an object describes its speed *and* direction. The velocity of each glider is indicated next to the v1 and v2 sliders. Click **Play**, and then click **Pause** just before the collision.
   a. What is the velocity of Glider 1? Include positive or negative. _______________
   b. In which direction does Glider 1 move? _____________
   c. What is the velocity of Glider 2? Include positive or negative. _______________
   d. In which direction does Glider 2 move? _____________

ACTIVITY A: **Momentum**	Get the Gizmo ready: • Click **Reset**.

APPENDIX K CONTINUED

Question: How does an object's momentum change when it collides with another object?

1. Explore: The Gizmo allows you to adjust the mass and initial velocity of each glider. Set up each of the following scenarios, and describe what happens when the gliders collide.
   a. The gliders have the same mass but different velocities.

   b. The gliders have the same mass and one glider is stationary.

   c. The gliders have the same velocity (but in opposite directions) and different masses.

2. Calculate: An object's **momentum (p)** describes how hard it is to stop. Momentum is equal to the product of mass and velocity: $p = mv$. If mass is measured in kilograms and velocity in meters per second, the unit of momentum is kilograms-meters per second, or kg•m/s.
   a. What is the momentum if the mass is 1.5 kg and the velocity is 4 m/s?

   ____

   Turn on **Show numerical data** and use the Gizmo to check your answer.

   b. How could you use the Gizmo to increase a glider's momentum?

3. Gather data: Click **Reset**. Set $\mathbf{m_1}$ to 3.0 kg and $\mathbf{v_1}$ to 2.0 m/s. Set $\mathbf{m_2}$ to 2.0 kg and $\mathbf{v_2}$ to -4.0 m/s. Fill in the left table, run the collision, and then fill in the right table.

Before Collision		
Glider	**Glider 1**	**Glider 2**
Mass		
Velocity		
Momentum		

APPENDIX K CONTINUED

After Collision		
Glider	**Glider 1**	**Glider 2**
Mass		
Velocity		
Momentum		

4. Calculate: To find the total momentum, add up the momentum of each glider. (Note: Pay attention to signs.)
   a. What was the total momentum of the two gliders before the collision? __________
   b. What was the total momentum of the two gliders after the collision? ___________
   Turn on **Show total momentum** to check your answers.

5. Experiment: Click **Reset**. Set up three collisions using any combination of masses and velocities you like. (The only rule is that the gliders must collide.) Record the mass, velocity, and momentum of each glider before and after the collision. Then, find the total momentum. Remember to include units.

		Glider 1			Glider 2			Total Momentum
		m	v	p	m	v	p	
1	Before							
	After							
2	Before							
	After							
3	Before							
	After							

6. Analyze: What do you notice about the total momentum of the two gliders?

7. Draw conclusions: The principle of **conservation of momentum** states that, in a closed system, the total momentum of all of the objects will remain constant. How do your experiments demonstrate conservation of momentum?
