

Integrating iPads with a Student Centered Approach in a Collaborative Classroom

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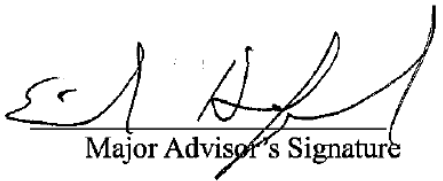
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### **Abstract**

This project was designed to integrate 21<sup>st</sup> century technology into a technical college level mathematics classroom through the use of iPads, AirPlay, HD notes, and Desmos. I wanted to give students the ability to share their collaborative work with the rest of the classroom through the use of technology. Mechanical devices for doing calculations date back thousands of years. The newest devices are ICTs (Information and Communication Technologies) such as iPads and smartphones. The students for this study used iPads that were integrated into a collaborative classroom using the Quantway Curriculum design by the Carnegie Institute. The project itself involves two classrooms and two different instructors. One class implemented iPads during Module 3, while the other class used iPads during Module 4. The intentions of this study are to have students utilize technology to deepen their overall understanding and retention of the material. This paper describes the implementation process of the ICTs and compares the results of average test scores for four different Modules as well as the comprehensive final exam. The average scores from the Module 1 Test and Module 2 Test scores were used to set a baseline performance between the two groups. The remaining two Module test scores and the final were analyzed, using the groups average scores, to show the positive gains that can happen when ICTs are integrated into a classroom.

## Chapter 1 - Introduction

The foundation for this project is based on over a decade of teaching and a desire to find ways to make mathematics more technologically interesting and interactive for students. This project is about the implementation of iPad Airs in a course entitled Mathematical Reasoning at CVTC (Chippewa Valley Technical College). The course delivery is face to face and is set in a collaborative classroom. The curriculum used was the Quantway Curriculum developed by the Carnegie Institute (Carnegie Foundation for the Advancement of Teaching, 2016). In this paper you will get a summary of the journey that I took to get to this point and how I integrated the iPad Airs into CVTC's Mathematical Reasoning course.

I started teaching at Viroqua High School in Viroqua, Wisconsin. I was at Viroqua for four years and taught Pre-Algebra, Algebra I, Geometry, and Algebra II. My students ranged from freshman to seniors with an overall high school population of approximately 300 students. Over 90% of Viroqua's student population identifies themselves as white, and 4 out of every 10 students are on free or reduced lunch. Generally speaking, the population in Viroqua is low income, largely comprised of retirees and moderately educated (Graphiq Inc., 2017).

The technology that was in my classroom consisted of one computer (at the teacher's desk), one television, one whiteboard, an overhead projector, and a data projector mounted to the ceiling. All the students sat in rows at their own desk, and all faced the whiteboard. As I recall, most of my students had an ICT (Information and Communication Technology), which consisted primarily of a cell phone with, very few being smart phones. Since every student did not have a

cell phone and computer lab time was hard to come by, incorporating ICTs into the classroom was very challenging.

My next position as an educator was as a Developmental Mathematics Instructor at Chippewa Valley Technical College, in Eau Claire, Wisconsin. Chippewa Valley Technical College serves an 11-county region and is one of 16 colleges in the Wisconsin Technical College System. Chippewa Valley Technical College serves approximately 16,342 students with 4,103.7 FTEs in 90 programs, 24 certificates, and 7 apprenticeships. The college's student population is 56% male and 44% female with an ethnicity of 90% white, 4% Asian, 2% Hispanic, 2% Black, 1% American Indian/ Alaskan Native, 1% Multiple, and < 1% Pacific Islander. As for resources, the college had every resource that Viroqua had but there were some differences. Instead of a desk and an overhead projector they had a teaching station and a document camera. Each teaching station had a control box that would let instructors switch between different resources with a push of a button. But as I started to use these resources more, I started to realize my students still were not engaged as much as I would like them to be. I started to explore ideas to move around more in the classroom and spend less time in the front of the room.

I can recall going to conferences and seeing presenters using smart boards. I was intrigued with the smart board and the potential they had to engage my students and enhance the presentation of the content. Then reality would hit when I would put in a request and realized a smart board was not in the budget. I started to look for different ways to bring technology into my instruction. I then started looking into a classroom set of tablets. Unfortunately, with recent budget restraints and cuts, I was told the funds were not available. I started to wonder how society views the importance of education. I was always under the impression that education is the key for a successful future. That education is humanity's great equalizer, a highway that

allows everyone to reach their fullest potential and provides everyone the ability to set higher personal and professional goals and become more engaged in our growing world while providing a greater contribution to the prosperity of one's family and community. In order to achieve this, investing in the resources and funding that educational institutions need is essential.

Unfortunately in Wisconsin, massive legislative cuts have forced Wisconsin higher education systems to make some difficult decisions. To offset the loss of funding from the state, Wisconsin colleges have merged departments, cut back on classes, and eliminated staff positions (Douglas-Gabriel, 2015).

This is not just an issue for the state of Wisconsin. As a country we need to be concerned about the direction we are taking education, especially with the latest details from the Trump administration FY 2018 federal budget. Matt Larson (2017), President of the NCTM (National Council of Teachers of Mathematics), provides a summary of the budget: the plan is to cut \$10.6 billion from federal education initiatives, including offering zero funds for professional development funding, especially important to states and math teachers; zero funds to support innovative programs and partnerships at colleges of education nationwide; zero funds for an important new block grant program that supports locally determined needs and programs, including STEM education efforts; and proposed cuts to career and technical education programs, despite the President's stated affinity for such programs. With all of the cuts happening at the state and federal levels, everyone should ask themselves, "How can we persevere?" Even with the discouraging decisions made by our elected politicians, I had a continued desire to find a way to integrate ICTs into mathematics.

While I was teaching a class in the spring of 2016, I challenged my students to find a way to help me present lectures while being mobile within the classroom. The class eventually led me

to an app called AirServer. AirServer turns your Windows PC into a universal mirroring receiver, allowing you to mirror your device's display using the built-in AirPlay, Google Cast or Miracast based screen projection functionality; one-by-one or simultaneously to AirServer (AirServer 2011). This app gave me the mobility to move around the room while presenting information and interacting with my students. The AirServer app is very similar to AppleAir. The college I am working at already had some classrooms with AppleAir. Unfortunately, the cost was too high and the demand was too low to install AppleAir in every classroom. AirServer was relatively inexpensive, with a cost from \$7.99 to \$11.99, for installing it to a classroom computer; in addition, the app to link up to it on any ICT was free. With AirServer I was able to have multiple students work on a problem while it was broadcast throughout the classroom. AirServer was just the app I was looking for. Most students would use their smartphones, which made things challenging due to their small size. Tablets, on the other hand, worked very well; unfortunately, not every student had a tablet. Getting a classroom set of tablets was my next undertaking.

I once again started by asking the powers that be; this time I explained how they would be implemented and utilized within the classroom. I received a lot of interest, but the budget was still an issue. I was then told about a Teaching Excellence Grant through our college. I applied for the grant, which would allow me the funds to purchase five iPads (choosing a different tablet was not an option because the IT department told me that the college would not support or approve a tablet purchase unless it was an Apple product). I was also able to convince my Dean to purchase a couple more iPads. Those, along with four iPads donated by the college's Curriculum of Professional Development department, put me at 11 iPads. I teach in a

collaborative classroom that has tables in clusters instead of desks in a row. Each table has three or four students that make up the group. My goal was to have at least one iPad for every group.

Up to this point in time, I had always taught in a traditional classroom and thought that a collaborative classroom would not work for a math class. In the spring semester of 2015 I was scheduled to teach my first class in a collaborative room. I had the ability to rearrange the classroom into a traditional style as long as I put the classroom back the way it was when I was finished. But time is always an issue during a 55-minute class period, so I decided I would adjust to the new layout. Throughout the semester, the student conversations and interactions with each other paved a new style of teaching for me. From that moment on I would request that all my classes be held in a collaborative classroom. It was only by chance that the College was in a transition period and looking for different and newer ways to teach developmental mathematics. This eventually led us to implementing the Carnegie Curriculum.

In the spring of 2015, my dean asked if I would like to be on an Accelerated Curriculum Committee. I was both willing and eager to be part of such a pivotal moment for the College. Our main objectives were to shorten the sequence for students to complete their math requirements while improving student success. At the time, our sequence would take a student up to four semesters to complete Pre-Algebra, Elementary Algebra, Intermediate Algebra, and then College Algebra. In a search for a new curriculum, I attended several conferences with other colleagues and administrators. We eventually went to a summer conference in 2015 for the Carnegie Institute. Carnegie's pedagogy and real world problems set in a collaborative classroom were just the curriculum we were looking for.

Carnegie Math Pathways, Statway and Quantway, are new approaches to developmental mathematics that:

- Shorten the math sequence and reduce transition points for students placed in remedial math in order to help them achieve college math credit and reach their academic completion goals.
- Offer a productively challenging curriculum relevant to students' lives and areas of study.
- Integrate productive persistence student supports into the curriculum.

Statway and Quantway are taught using common curricula, assessments, an online platform, and innovative instructional approaches (Carnegie Math Pathways 2017).

The Carnegie Curriculum is broken into two tracks: Quantway and Statway.

Quantway is focused on quantitative reasoning that fulfills developmental requirements with the aim of preparing students for success in college-level mathematics (Carnegie Math Pathways 2017). The goal of Quantway is to promote success in community college mathematics and to develop quantitatively literate students. Statway is focused on statistics, data analysis, and causal reasoning, combining college-level statistics with developmental math. It is designed to teach mathematics skills that are essential for a growing number of occupations and are needed for decision-making under conditions of uncertainty (Carnegie Math Pathways 2017).

Each of these tracks are broken up into Parts I and II. The curriculum style and success rates for both tracks were very encouraging to our committee. We presented our recommendation, and our college decided to adopt and implement both curricula at the same time; notably, we were the first institution in the nation to do so.

The Quantway I curriculum at our college is called Mathematical Reasoning while the Quantway II curriculum is called Quantitative Reasoning. Mathematical Reasoning is broken

into four Modules with each lasting approximately three weeks, each followed by a Module test. The course concludes with a comprehensive final exam. The timeline and sequence for the course can be viewed in Appendix B. Sections have been highlighted in Appendix B to emphasize the timeline for when the iPads and Desmos were implanted into the curriculum. This paper focuses on the implementation of iPads in the Mathematical Reasoning course. As a part of this study, students used the iPads as a mechanical device to help with calculations and modeling concepts like linear functions, system of equations, exponential growth and exponential decay.

## Chapter 2 - Review of Literature

Over the years mathematics has experienced several false dichotomies such as new mathematics versus old mathematics, computational skill versus concept development, discovery versus expository learning, and calculator versus non-calculator curriculums. To consider whether to use smartphones, iPads, tablets or other ICTs (Information and Communication Technologies) is to create another false dichotomy in mathematics. “Today’s students are attached to technology, including mobile devices, both in and out of school, and it is important that our schools are able to leverage this reality in a way that supports and expands student learning,” said American Association of School Administrators Executive Director Daniel Domenech (CoSN, 2012). Educational curriculum is always evolving. ICTs are just the next step in the evolution process. The next decade and beyond could be transformational in incorporating mobile technologies in both formal and informal education to better meet the needs of learners and teachers everywhere (Shuler, Winters, & West, 2013). There are several contexts in which ICTs could be used to enhance instruction, while in other contexts are equally inappropriate. These differences must be identified and treated accordingly in developing new pedagogies and curriculums. “When policy and practice are aligned, the amazing possibilities presented by this fact surely outweigh the challenges. Creating that alignment is our first step,” said National Association of State Boards of Education Deputy Executive Director Bradley J. Hull (as cited in CoSN, 2012). This suggests a larger question for ICTs’ usage of why, when, and how they should be used.

Today’s students are surrounded by technology. We are exposing children with newer, faster, and better technology every day, so why then would educators not incorporate the technology they are utilizing into the learning environment? Over the next fifteen years, the

implementation of mobile learning projects and the pedagogical models they support should be guided not only by the advantages and limitations of mobile technologies but also by an awareness of how these technologies fit into the broader social and cultural fabric of communities (Shuler, Winters, & West, 2013). ICTs are just the next progression in technology to integrate into the pedagogy of our curriculums. This leads us to the first question that needs to be answered: Why should educators implement ICTs in the curriculum they are teaching? Carr (2012) states:

Researchers have encouraged the use of technology in the classroom since the early 20<sup>th</sup> century. The technology that has been utilized by educators in the 20<sup>th</sup> century to help provide high quality instruction has been overhead projectors, televisions and video home system tapes. More recently, teachers have used a variety of handheld technologies such as iPods, laptops, and smart phones to increase engagement and student learning.

The technology debate with ICTs is the next step in utilizing mechanical devices in a mathematics classroom.

The history of mechanical devices used to enhance calculations began thousands of years ago. Historians believe that the abacus was the first tool used for calculations (Fernandes, 2015). Although no one knows exactly when the first tool like the abacus was used, there is speculation that the Babylonians used a similar device as early as 2400 B.C. The oldest abacus in existence is the Salamis Abacus (Figure 2.1), kept in the National Museum of the Epigraphy in Athens and is dated around 300 B.C. Although the abacus still might be used in some places in parts of the world, it is now used primarily as a toy by children.

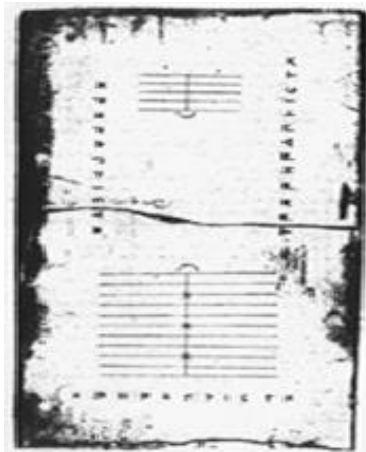


Figure 2.1

It took approximately 3600 years before the next device for mechanical calculations, the slide rule, would be invented. The slide rule was invented by William Oughtred, a fellow at King's College of Cambridge University. Oughtred is considered one of the world's great mathematicians due to his writings on the subject and his invention of the logarithmic slide rule (Encyclopedia 2004). The next advancement in mechanical calculations would have to wait another 200 years after the invention of the slide rule.

It wasn't until 1820 when French mathematician and inventor Charles Xavier Thomas de Colmar of France created the four function Arithmometer. Arithmometer was popular for approximately 90 years and was the first commercial mass-produced calculating device that could perform addition, subtraction, multiplication, and, with some more elaborate user involvement, division (Swaine & Freiberger, 2017). Although other advancements were made since 1820, the slide rule would continue to be the most popular tool used for mechanical calculations for approximately the next 350 years.

In 1967 Texas Instruments created the first hand held prototype calculator called the Cal Tech (Ball 1997). The original 1967 Cal Tech (Figure 2.2) prototype can be found in the

Smithsonian Institution's National Museum of American History. Although the Cal Tech was never sold commercially, it did lead to the development of hand-held calculators. In 1971 the first two hand-held calculators were sold commercially, and they were the Canon Pocketronic (1.8 pounds, 4" wide, 8.2" deep, 1.9" thick, and sold for \$395) and Sharp EL-8 (1.6 pounds, 4" wide, 6.5" deep, 2.8" thick, and sold for \$345). Now, several different calculators from basic four function calculators to graphic calculators are available. (cite this)



Figure 2.2

The use of mechanical devices is not new; it has just transformed over the last 4000 years. The newest transformation is ICTs such as smartphones, iPads, and tablets. As educators we need to ask ourselves, how can we make this shift towards ICTs?

It is a common belief that the incorporation of computer technology into mathematics teaching and learning motivates and engages students (Pierce & Ball, 2009). Is this not part of what we strive for in our pedagogy as educators: to motivate, engage, and educate our students? Early research supports the notion that these devices can lead to measurable learning benefits, says Lucy Gray, project director of the Consortium for School Networking's Leadership for

Mobile Learning initiative (Robledo, 2012). Furthermore, the iPad has specialized applications in which multiple senses (e.g., auditory, visual, and tactile) are incorporated; the use of multiple sensory inputs has been shown to reinforce student learning and to achieve a variety of mathematics objectives (Carr, 2012). Understandably, there are some concerns about incorporating mobile devices in the classroom. One concern as an educator is that the technology could diminish the content and understanding in the curriculum. Then again, so can bad teaching practices in a traditional curriculum. Like any new curriculum that is adopted in a subject, it must be complemented with good pedagogy. When good pedagogy supports the incorporation of technology into mathematics teaching and learning, ICTs have immense potential to enhance students' experiences with mathematics (Attard & Northcote, 2011). A way to move forward with the integration of ICTs is to look at what has already been done, which raises the question of when should we integrate ICTs.

There is a simple answer to when we should integrate ICTs and the answer is “now.” A quick look on the internet will show educators implementing ICTs globally throughout different age levels. Aronin & Floyd (2013) provide examples of two educators integrating ICTs in preschools. The first example is Ms. Christa, a preschool teacher who uses Monkey Math app in her classroom. Monkey Math is an interactive game using basic mathematical concepts which include patterns, counting, number recognition, tracing, and addition. Another example is preschool teacher Ms. Lena, who uses a BridgeBasher app. The BridgeBasher app allows students to design their own bridge and test its strength. Other apps that these two teachers use are My First Tangrams HD (A Wood Tangram Puzzle for kids), I Learn With Poko: Seasons and Weather!, Builder Block Preschool, and Build a Robot (Aronin & Floyd, 2013).

Carr et al. (2012) write about the positive effects of ITCs in two different Virginia middle schools. In their study the participating instructors used 1:1 iPads to aid in the instruction of number and number theory, computation and estimation, measurement, geometry, probability and statistics, patterns, functions, and algebra. The experiment consisted of 104 students, 48 from the control group and 56 from the experimental group, and took place over one academic quarter of nine weeks. In this particular study there was no significant gain when comparing the variance of the two groups' results from the pretest and posttest. The experimental group only showed a growth of 0.07% compared to the control group. There have been several other 1:1 iPad studies that have shown similar results. Carr et al. (2012) makes a point to mention that at first a negative impact on teaching and learning may be experienced. However, numerous academic studies have shown significant positive correlations between technology, student learning, and mathematics achievement (Carr, 2012). Educators thinking of implementing ICTs into their classroom should realize that the impact on students might not be immediate. It usually takes five to eight years for an innovation to be implemented fully and for the impacts of the innovation to be discernible (Holcomb, 2009). ICTs have the ability to change the pedagogy that teachers are currently using and educators have now become pioneers with regards to integrating ICTs into our classrooms.

There are already educators who have proven success with programs such as the K-Nect project in North Carolina. Robledo (2012) discusses Project K-Nect, which took place in a ninth-grade class for at-risk students. These particular students were given smartphones because they had little to no access to computers or internet at home. Through the use of smartphones, students were able to access supplemental math material and connect socially with their peers and instructors. As a result of this project, "almost two-thirds of the students were taking

additional math courses, and over 50 percent are now thinking about a career in the math field as a result of participating in Project K-Nect” (Robledo 2012). Teachers at the North Carolina high school reported that Project K-Nect students have increased each of the following: responsibility for their education, collaborative learning skills, contributing to problem-solving discussions, and their participation in classes as both leaders and peer tutors.

Ingraham (2013) describes a project that uses two apps, Doodle Buddy and Keynote, to explore and illustrate geometric terminology in shapes and objects in the real world. In this study iPads were used to check for understanding and to reinforce the vocabulary that was used throughout the semester. Every student was given an iPad and a list of the geometry terms. The students were instructed to use the iPad’s camera to take pictures of real-life examples of those words. The checklist included 21 options that were written using geometric terminology such as two parallel lines that are NOT horizontal or vertical, supplementary angles that are NOT adjacent and NOT right angles, vertical angles formed by two lines that are NOT perpendicular, corresponding angles where the parallel lines are NOT horizontal nor vertical and the transversal is NOT perpendicular. Once the students photographed the image they would then use two different apps. The first app, Doodle Buddy, would allow the student the ability to edit the picture and illustrate the terminology they found. The second app, Keynote (much like PowerPoint), allowed the students to put their new images into a presentation to present to the class. Figure 2.3 is an example of student images that were designed in Doodle Buddy and illustrated on a presentation slide that was designed using the app Keynote. The use of multiple representations in mathematics classrooms is vital and can help students shift from procedural understanding to conceptual understanding, which will allow them to continue to be successful in high level mathematics courses (Ingraham, 2013). It is educators like Ingraham who are finding

ways, one step at a time, to improve education by utilizing ICTs in the classroom. The final question that needs to be addressed is, how do educators get the ICTs required for starting a program that implements ITCs into the classroom?



Figure 2.3

One of the many challenges for institutions, educators, and students is determining which mobile devices to integrate and the cost of those items. One way to help curb the cost of devices is to implement a BYOD (bring your own device) or BYOT (with T standing for technology). According to a report from Pew Research Center (2015) 92% of adults own a cell phone, 68% own a smartphone, 73% own a desktop or laptop, and 45% own a tablet computer. Another report from the Pew Research Center (2015) indicates that 88% of teens have or have access to cell phones or smartphones. Since a majority of students already have a cell phone or have access to one, it would be of no additional cost to use them in the classroom. For the small percentage of students who do not own a mobile phone or tablet, a solution could potentially be checking one out from the educational institution or community library.

## CONCLUSION

The educational system is always looking for new and innovative ways to prepare today's students for tomorrow's opportunities. Education is about knowledge and new experiences for students. The global technology that is currently available is priceless. The time to offer this amazing resource to students is now. Regardless of the obstacles, educators need to find ways to incorporate 21<sup>st</sup> century technology into today's classroom. The potential growth that ICTs can have on students' education has yet to be determined. As educators our next goal is to find ways to enhance and enrich learning through the use of ICTs. This project is an attempt to do that by integrating iPads into a technical college math course.

### Chapter 3 - Methods

This study was conducted to see if integrating iPads into a collaborative classroom would increase understanding and retention of the material. This study was designed to answer these following questions.

1. Did integrating ICTs into the experimental groups' curriculum increase the mean score on the Module 3 Test?
2. Did integrating ICTs into the experimental groups' curriculum increase the mean score on the Module 4 Test?
3. Was there a noticeable difference in the mean score on the final exam between the two groups?
4. Did students participating in this experiment have a higher mean test score when compared to the previous semester?
5. Did students participating in this experiment have a higher mean final exam score when compared to the previous semester?

For the sake of this study we will call the two classes Group A and Group B. Group A consisted of 19 students who all agreed to participate in this study. Group B consisted of 16 students, and only 14 were willing to participate in the study. Both sections used the material from the Carnegie Curriculum and followed the same timeline (Appendix B – Curriculum Timeline). In this study the experimental group integrated iPads and Desmos into four sections of a Module. The control group worked directly out of the textbook and workbook with no additional resources. In the first part of the study, during Module 3, Group A was the experimental group while Group B was the control group. In the second part of the study, during Module 4, Group B became the experimental group while Group A was the control group.

### Module 3 Implementation

In Module 3, Group A used the iPads and Desmos to illustrate the written solutions from problems in the following four sections. For each of the four sections the objectives to be covered in the sections are:

#### *3.1 Salary per Minute*

By the end of this lesson, you should understand that

- units can add meaning to the numbers that result from calculations.
- linear models are appropriate when the situation has a constant rate of increase/decrease.
- the rate of change (slope) has units in context.
- two quantities can be written as a rate and then graphed to visualize the linear relationship.

By the end of this lesson, you should be able to

- write a rate as a fraction.
- use a unit factor to simplify a rate.
- identify a linear equations slope and intercepts.
- make a linear model when given data or information in context.

#### *3.2 The Cost of Driving*

By the end of this lesson, you should understand that

- precision should be based on several factors, including the size of the numbers used and the precision of the original values.

- the difference between a positive slope and a negative slope.
- a system of equations is two or more functions.
- two equations that intersect at a point have the same solution.

By the end of this lesson, you should be able to

- solve a complex problem with multiple pieces of information and steps.
- investigate how changing certain values affects the result of a calculation.
- solve for the point of intersection of two functions.

### *3.4 Breaking Down the Variables*

By the end of this lesson, you should understand that

- a variable is a symbol that is used in algebra to represent a quantity that can change.
- many variables can be present in a scenario or experiment, but some can be held fixed in order to analyze the effect that the change in one variable has on another.

By the end of this lesson, you should be able to

- evaluate an expression.
- informally describe the change in one variable as another variable changes.

### *3.6 Balancing Blood Alcohol*

By the end of this lesson, you should understand that

- addition and subtraction are inverse operations.
- multiplication and division are inverse operations.
- solving for a variable includes isolating it by “undoing” the actions to it.

By the end of this lesson, you should be able to

- solve for a variable in a linear equation.
- explicitly write out the order of operations to evaluate a given equation.
- define the parameters of the linear equation.
- graph the linear equation.

In all of the sections, both groups were required to do the calculations manually and then make predictions about what would happen if certain parameters were changed. The control group did all the graphing on paper using the graphs supplied in the workbook. The experimental group used the iPads and created linear models in Desmos to verify their previous predictions. After the experimental group was done with their Desmos model, one group was selected for each question. The selected group then demonstrated their results by linking their iPad up to the LCD projector and LCD televisions via the teacher’s station and AirPlay.

In 3.1 Salary per Minute students used the iPads and Desmos to help make deeper connections on the following three questions.

1. (a). According to Toyota’s website, a 2014 Prius can get an estimated 51 miles per gallon (mpg) in the city and 48 mpg on the highway. How many miles will you be able to drive in the city if you have 4.5 gallons of gas?  
(b). How many gallons of gas will you need to drive 3,450 miles?
3. Many states have banned texting while driving because it is dangerous, but many people do not think that texting for a few seconds is that harmful. Suppose you are

driving 60 miles/hour and you take your eyes off the road for four seconds. How many feet (ft) will you travel in that time?

5. Nurses are often required to calculate dosages. That is, they must check the order that a doctor has given for the administration of a drug and decide whether the dosage is correct. Suppose a doctor has ordered a dose of 0.1 gram of a medication. The drug comes in a solution concentration of 200 mg per milliliters. How many milliliters of this solution is required?

The first question in Section 3.1 required the students to calculate the distance a car could travel given an estimated 51 miles per gallon (mpg) in the city and 48 mpg on the highway using 4.5 gallons of gas. Next, each cohort made a prediction about what would happen if the mpg or quantity of gas fluctuated. The students were then given the iPads and asked to write the linear model for this question using Desmos (Figure 3.1). In order for the class to feel comfortable writing equations in Desmos, the first question was done as a class and with guidance from the instructor. The groups then used the linear models in Desmos to check the validity of their previous predictions.

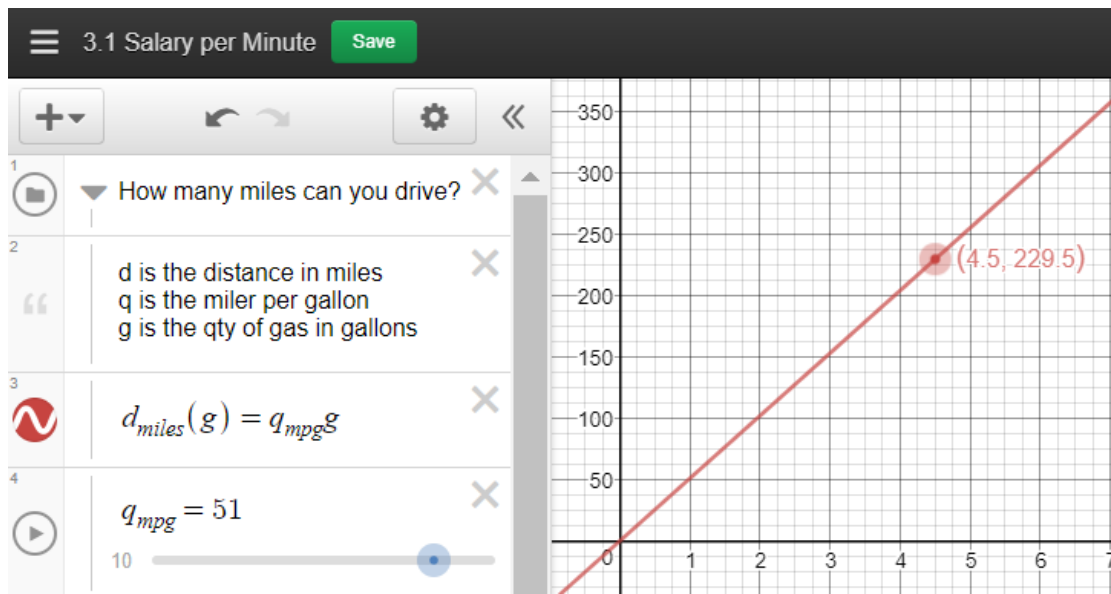


Figure 3.1

The next question that the students used the iPads on was Question 3. For this question the students used Desmos to model the distance traveled going 60 mph for four seconds. They were to assume the four seconds represented the length of time it takes to read and respond to a text message. Next, each group was asked to make predictions and describe what the linear model would look like if speed and/or time changed. Each group would then adjust the parameters in their Desmos equation to check the accuracy of their prediction (Figure 3.2).

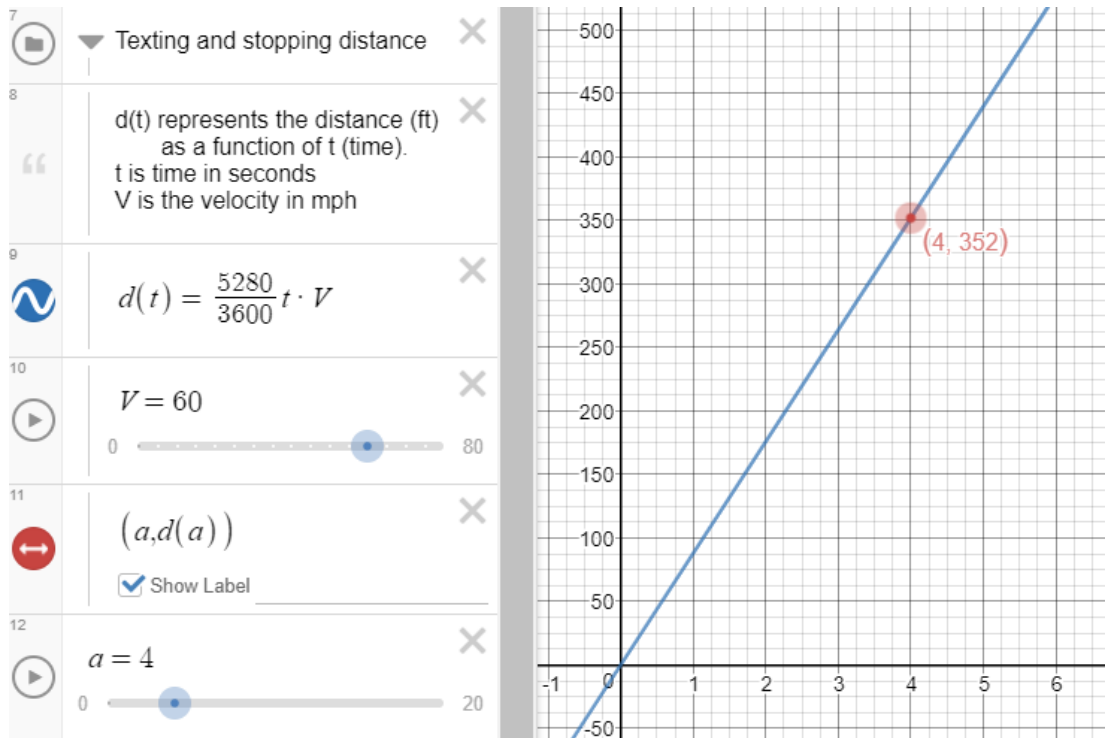


Figure 3.2

The final question in 3.1 was Question 5. Question 5 was about calculating the amount of medicine, in milliliters, to administer to someone given different dosage strengths on a bottle. In this question the students first needed to manually calculate the dosage amount and then decide if the amount seemed reasonable. Each group then had to write their own linear equation in Desmos from the information they had previously calculated. A new group was then selected to link up to the teaching station and present their linear formula and findings to the class (Figure 3.3). For the first two questions, the students were able to use the scale that was demonstrated in Question 1 to answer both Questions 1 and 3. In Question 5 the students had to experiment with different scales for both axes to make the information presentable.

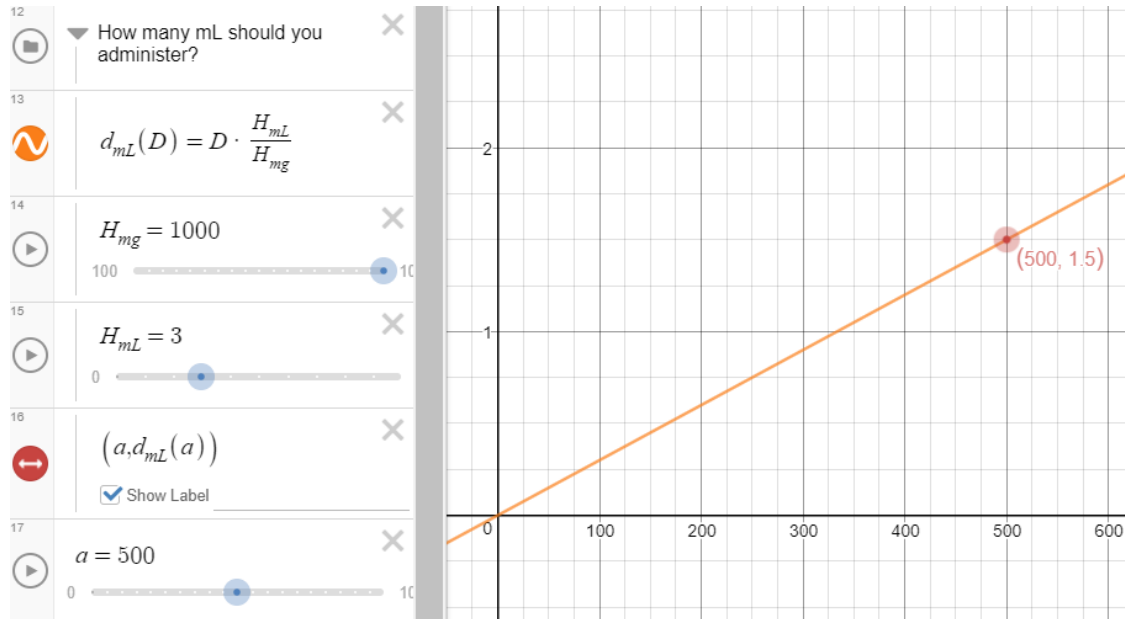


Figure 3.3

In the next section, *3.2 The Cost of Driving*, students investigated the cost difference between driving an owned vehicle and using a rental. A class discussion was held to decide what variables must be considered when doing this type of comparison. In the case of the owned car, the suggested items the students mentioned were miles driven, gas price, mpg of the vehicle, general maintenance, tires, and repairs. For the cost of driving the rental car, items the students said they needed to consider were gas price, length of trip, mpg of the rental, and the initial price of renting the vehicle. The students were then given the following specific information on each of the items they listed and were asked to calculate the cost for both vehicles.

Cost of driving a rental car for a round trip.

- Price of gas: \$3.50/gallon
- Length of trip (one way): 193 miles
- Gas mileage of rental car: 40 miles/gallon

- Price of the rental car: \$98.98 plus 15.3% tax (Gas is not included in the rental price and the car must be returned to the rental agency with a full tank.)

Cost of driving your own car for a round trip and maintenance cost for the car:

- Price of gas: \$3.50 per gallon
- Length of trip (one way): 193 miles
- Gas mileage: 22 miles per gallon
- General maintenance (oil and fluid changes): \$40 every 3,000 miles
- Tires: Tires for Jenna's car cost \$920; they are supposed to be replaced every 50,000 miles
- Repairs: The website Edmunds.com estimates repairs on a three-year-old 2006 4Runner will be approximately \$328 per year; this is based on driving 15,000 miles.

Next, the students were asked if the more expensive option would ever be the more economical choice. A group was then selected to link their iPad to the projector and present their findings (Figure 3.4). Next, a class discussion was held about what was happening on the graph. Students then had to answer specific questions that were asked about the importance of the y-intercepts and the point of intersection.

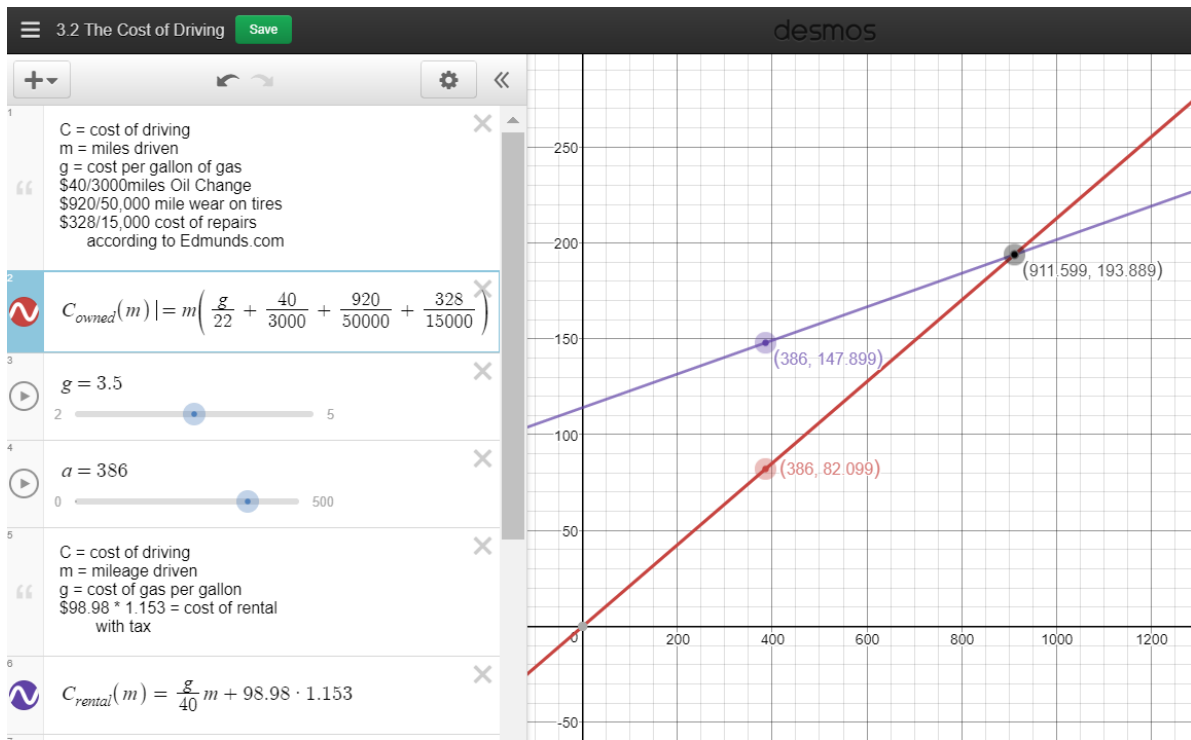


Figure 3.4

The third section that the students utilized the iPads, Desmos and AirPlay for was 3.4 *Breaking Down the Variables*. This section is a more detailed investigation of the variables used to calculate the stopping distance of a vehicle. This section also takes into account the body's time to react and apply the brakes. The lesson started by asking the class what factors we should take into account when thinking about stopping distance. The students were quick to reply with speed and road conditions. They were then shown two equations,  $\left(d = \frac{V_0^2}{2g(f+G)}\right)$  and  $\left(t = \sqrt{\frac{d}{192}}\right)$ , and asked to define what each variable represented. After the students defined each variable, we spent the rest of the class focusing on velocity ( $V_0$ ) and distance ( $d$ ) in the first equation and time ( $t$ ) and distance ( $d$ ) in the second equation.

For the first equation  $\left(d = \frac{v_0^2}{2g(f+G)}\right)$  the students used 0.8 for  $f$  (coefficient of friction between the roadway and the tires), 0.05 for  $G$  (roadway grade), and 32.2 for  $g$  (gravity in ft/sec<sup>2</sup>). The students were then required to predict the distance needed to stop a vehicle when traveling through a residential neighborhood at 25 mph. Predictions from the students ranged from 10 feet to 40 feet. Next, students had to do the calculations on paper. Their first obstacle was changing 25 mph to feet per second. The second challenge was recognizing this calculation would only allow them to compute the distance required to stop a vehicle. The students still needed to take into account the reaction time to start applying the brake.

To find the group's average reaction time, each group member would try catching a randomly dropped ruler between their fingers. Figure 3.5 illustrates the process that each student did to record the distance on a ruler. Each group member would catch the ruler three times with each hand and record those distances. After each group member was done, the next step was to calculate the group's average distance. Once the students had the group's average, they were

instructed to calculate the reaction time using the formula  $\left(t = \sqrt{\frac{d}{192}}\right)$ .

*Illustration of the ruler test to calculate reaction time.*



Figure 3.5

The final step for each group was to transfer their written work into working linear models on Desmos. Another group was selected to present their linear models to the class through AirPlay. The class was then asked to discuss the following four questions:

1. What will happen to the stopping distance if the average reaction time to stop increased? How would this change affect the graph?
2. What will happen to the stopping distance if the velocity increased? How would this change affect the graph?
3. What will happen to the stopping distance if the group average for catching the ruler doubled?
4. What will happen to the stopping distance if the velocity doubled?

Each group was allowed to discuss the questions and make predictions. For Questions 1 and 2 everyone in the class agreed that the stopping distance would increase and the graph would grow faster. A great discussion between groups started when answering Questions 3 and 4. All the groups agreed the stopping distance for Questions 3 & 4 would increase but they could not agree on how much or if it would double.

For Question 3 the class was divided on the stopping distance increasing a little more while others thought the distance should double. Each group was given the opportunity to defend their hypothesis and try to convince the other groups to side with them. This question was eventually tested on Desmos to settle the dispute (Figure 3.6). After modifying the parameters in Desmos all the groups were surprised the distance only increased by 2.685 feet. The class then looked at the original equation,  $\left( t = \sqrt{\frac{d}{192}} \right)$ , and discussed what happens to a number when they take the square root of it. A “Fist of Five” formative assessment was used to check for understanding. A one meant they were still confused and didn’t understand while a five meant

they were confident in understanding the outcome. A majority of the class held up four or five fingers with only two students holding up three fingers.

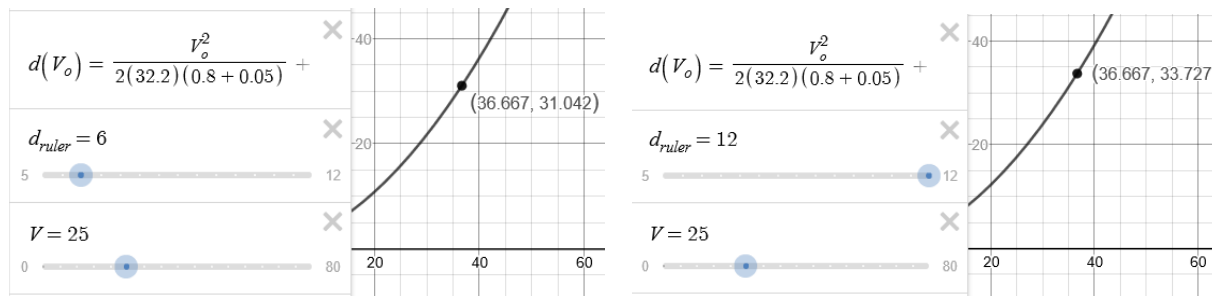


Figure 3.6

The students also had a discussion about their hypothesis for Question 4. Most students were convinced that this would definitely double the stopping distance. The remainder of the students were predicting that the distance would more than double, with a few of those students claiming it would quadruple. Both groups had a chance to explain their reasoning. A majority of the class was in agreement after hearing two students explain why the distance would quadruple. Ultimately, this question was also answered using Desmos (Figure 3.7). The class then recapped what happens to quantities when powers are applied to them. A “Fist of Five” formative assessment was used to check for understanding; five students held up four fingers while the rest of the class held up five.

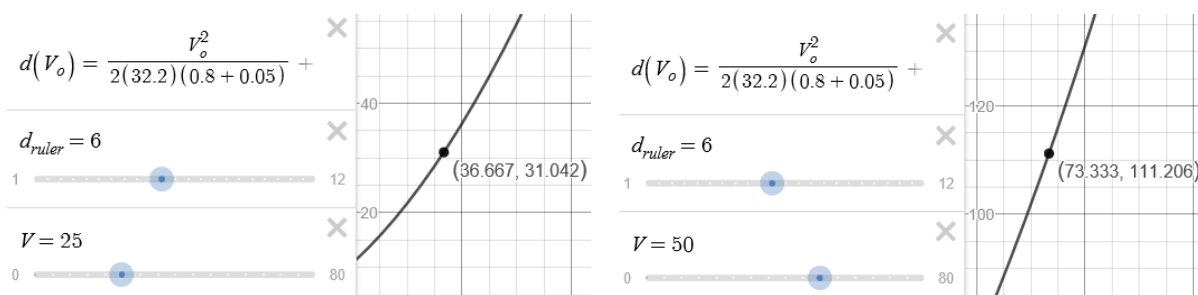


Figure 3.7

The last section this group of students used the iPads and Desmos on was for 3.6 *Balancing Blood Alcohol*. For this section the students used a formula  $(B = -0.015t + \frac{2.84N}{W*r})$  developed by Swedish physician, E.M.P. Widmark. The formula was developed for estimating an individual's BAC (blood alcohol content) and is used by forensic scientists (Carnegie Foundation for the Advancement of Teaching, 2016). The students were asked to look at the formula and predict what each variable represented. As a class the students derived the correct assumptions for B (BAC), t (length of time drinking in hours), N (number of drinks), and W (the individual's weight). The only variable the students weren't sure about was "r." The students were eventually told that "r" represented the distribution rate of alcohol through the body. They were also given rate disbursement values for men (0.68) and women (0.55).

The students were then given a problem and asked to estimate an answer. Each group was allowed to discuss the problem and come up with one unified answer. The groups' answers for the following problem ranged from "he can drive home right after the game" to "he should wait one hour before driving home."

While watching the Packers game at a friend's house a man (weighing 205 pounds) had 8 drinks. The game lasted four hours. Is the man's BAC below the legal limit of 0.08? If the man's BAC is higher than 0.08, how much longer should the man wait before he drives home?

Each group was then asked to calculate the man's BAC and write a linear model in Desmos to represent the problem. Figure 3.8 is a Desmos graph that one group created. The class was surprised that man had to wait over an hour before his BAC would be at 0.8. The last part of this section allowed the students to put in their own values to see what their BAC might be if

they find themselves in a similar situation. Several of the students were shocked by their calculated BAC and claimed that they should call a cab or spend the night.

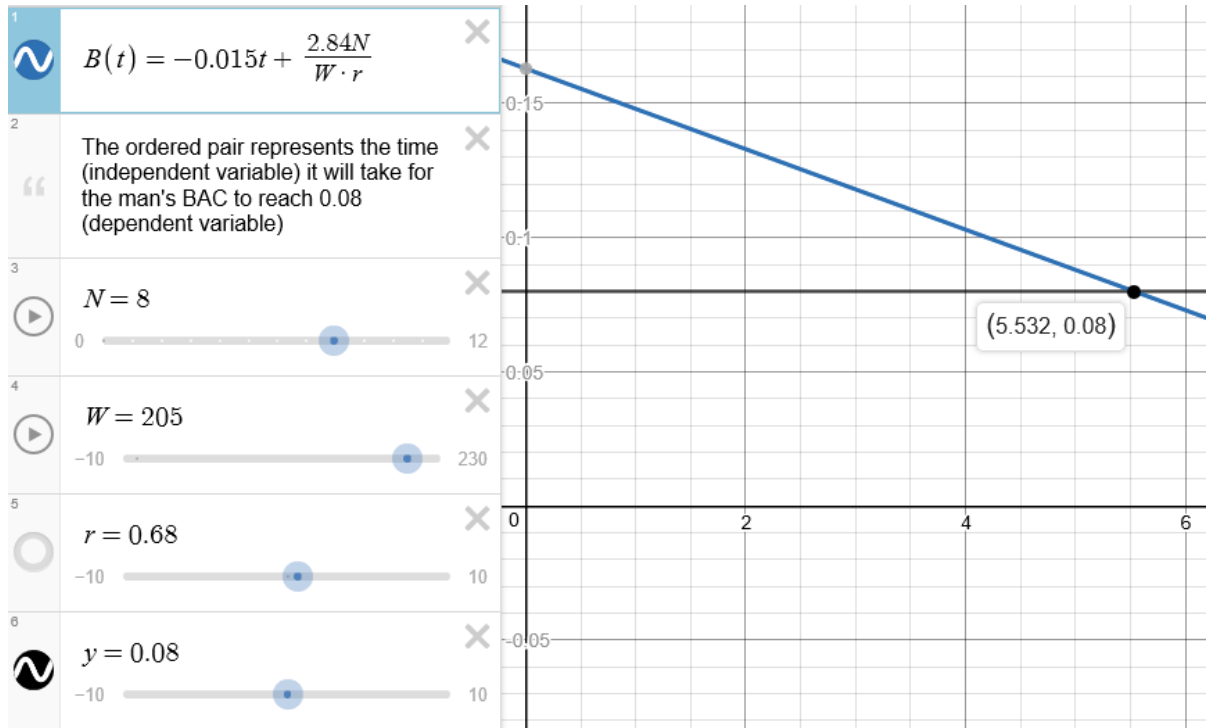


Figure 3.8

The control groups did all the graphing on paper with graphs supplied in their workbook. At the end of Module 3, the same test was given to both groups. The students in the experimental group (Group A) were allowed to use a calculator and Desmos. The control group (Group B) were only allowed to use a calculator. The results of this test are detailed in Chapter 4 - Results.

## Module 4 Implementation

In Module 4, Group B became the experimental group and used the iPads and Desmos to illustrate the written solutions from problems in four sections. The objectives for each of the four sections are:

### 4.2 Comparing Change

By the end of this lesson, you should understand that

- linear models are appropriate when the situation has a constant rate of increase/decrease or can be approximated by a constant rate.
- the rate of change (slope) has units in context.
- the difference between a positive slope and a negative slope.
- the linear models for authentic situations have limitations in using them to make predictions.

By the end of this lesson, you should be able to

- make a linear model when given data or information in context.
- calculate a slope given data or information in context.
- estimate the value that makes two linear models equivalent.

### 4.5 Compounding Interest Makes Cents

By the end of this lesson, you should understand that

- compounding is repeated multiplication by a compounding factor.
- compounding is best expressed in terms of exponential growth, using exponential notation.
- exponential growth models the compounding of interest on an initial investment.

By the end of this lesson, you should be able to

- calculate the earnings on a principal investment with annual compound interest.
- write a formula for annual compound interest.
- compare and contrast linear and exponential models.

#### 4.6 Compounding Makes More Cents

By the end of this lesson, you should understand that

- there are differences and similarities between exponential growth and decay.

By the end of this lesson, you should be able to

- use the compound interest formula for different compounding periods.
- write an exponential decay model.

#### 4.8 Green Savings

By the end of this lesson, you should understand that

- mathematical modeling and quantitative reasoning can be used to help make personal financial decisions.

By the end of this lesson, you should be able to

- identify missing information.
- demonstrate an ability to determine reasonable values for missing information.
- construct a linear model of a savings scenario.
- describe in words and graphs the effect changes in assumptions have on linear models.

In all of the sections, students were required to do the calculations manually and then make predictions about what would happen if certain parameters were changed. The students in the experimental group would then use the iPads and create models in Desmos to verify their previous predictions. One group would be selected for each question to demonstrate the linear equation they produced on Desmos by linking their iPad up to the LCD projector and LCD televisions via the teacher's station and AirPlay.

The first section that Group B used the iPads and Desmos on was *4.2 Comparing Change*. In this section students needed to graph the average gallons per person of milk and soda consumption. They were informed that yearly milk consumption has been on a steady decline while soda consumption has been on the rise. The amount of milk consumed by a person in 1950 was 40 gallons and in 2000 was 20 gallons. The amount of soda consumed by a person in 1950 was 10 gallons and in 2000 was 50 gallons. While working in their groups, the students had to work the problem out on paper. Their next task was to write a linear model for milk and soda consumption in Desmos. The first model involving the milk consumption was led by the instructor. Figure 3.9 represents the combined work from the instructor and a student group. Next, the group had to work together to come up with a model for soda consumption. After all the groups had their linear models in Desmos they were asked to answer three questions:

1. What does the point of intersection represent?
2. What do the y-intercepts tell us about this problem?
3. What do the x-intercepts tell us about this problem?

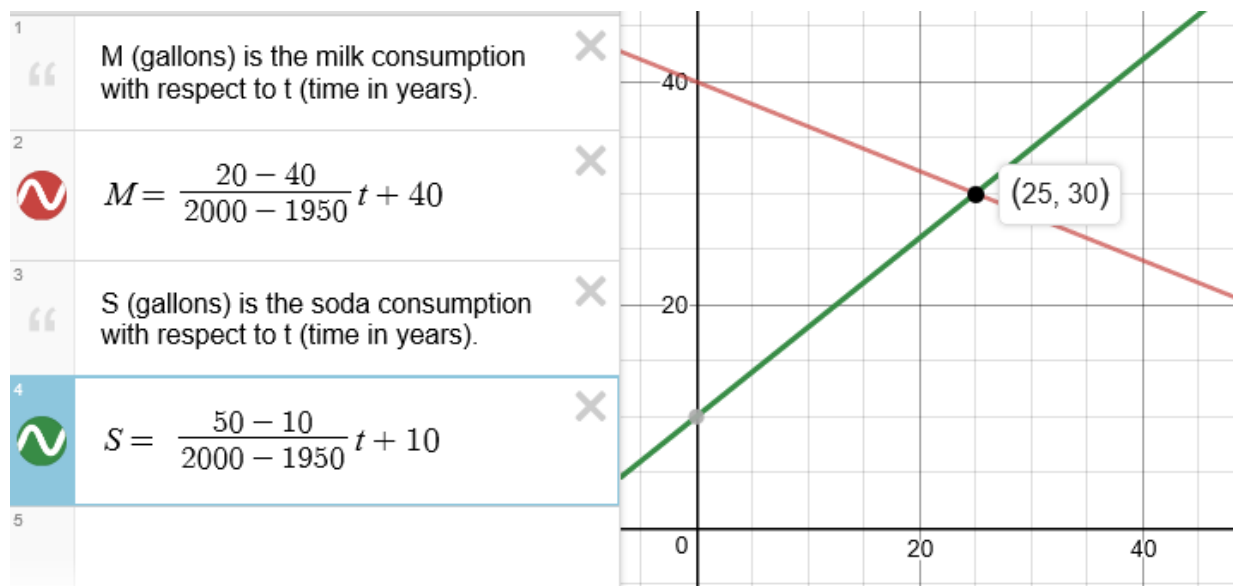


Figure 3.9

The next section that utilized iPads, Desmos and AirPlay was section 4.5 *Compounding Interest Makes Cents*. In this section the students were given information about a \$2000 investment that compounds yearly for five years at an APR (annual percentage rate) of 5%. The first two years are modeled in an equation for the students:

$$\text{Year 1: } \$1000 + \$1000 \cdot .05 = \$1000(1 + 0.05) = \$1000 \cdot 1.05$$

$$\text{Year 2: } \$1000 \cdot 1.05 = \$1000 \cdot 1.05^2$$

While working in their groups the students finished the series for the entire length of the investment. The groups were then asked to write a general formula that could be used to model any number of years. A group was selected to link their iPad to the teacher's station and present their information (Figure 3.10). Students were then asked to use their Desmos models to find the length of time for the investment to reach \$2,500. The answer to these questions can be seen in the following figure that was created by one group in Desmos. The answers were given as ordered pairs.

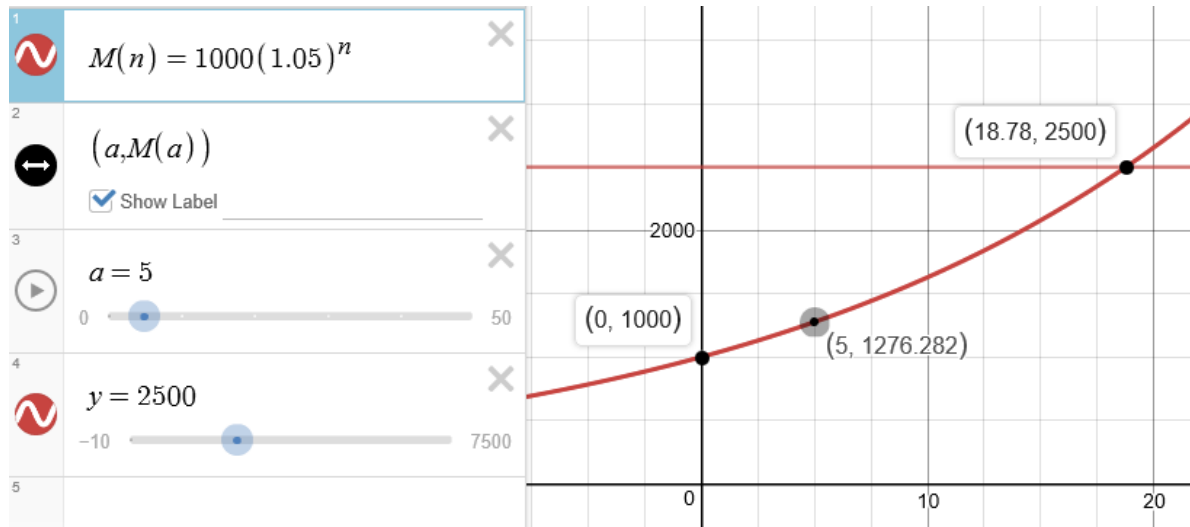


Figure 3.10

The next section, *4.6 Compounding Makes More Cents*, had the students do two different models involving interest. The first model involves compounding with different periods of time. The groups worked on deriving a formula similar to the previous chapter. The model that the groups came up with is as follows:  $A = P \left( 1 + \frac{r}{n} \right)^{nt}$ . The students were then given a problem situation to apply the new formula. The parameters of the problem were as follows: Principal = \$1000 with a 12% APR compounded monthly for a term length of two years. The students first worked the problem in their booklets and then transferred the information to Desmos for further investigation (Figure 3.11).

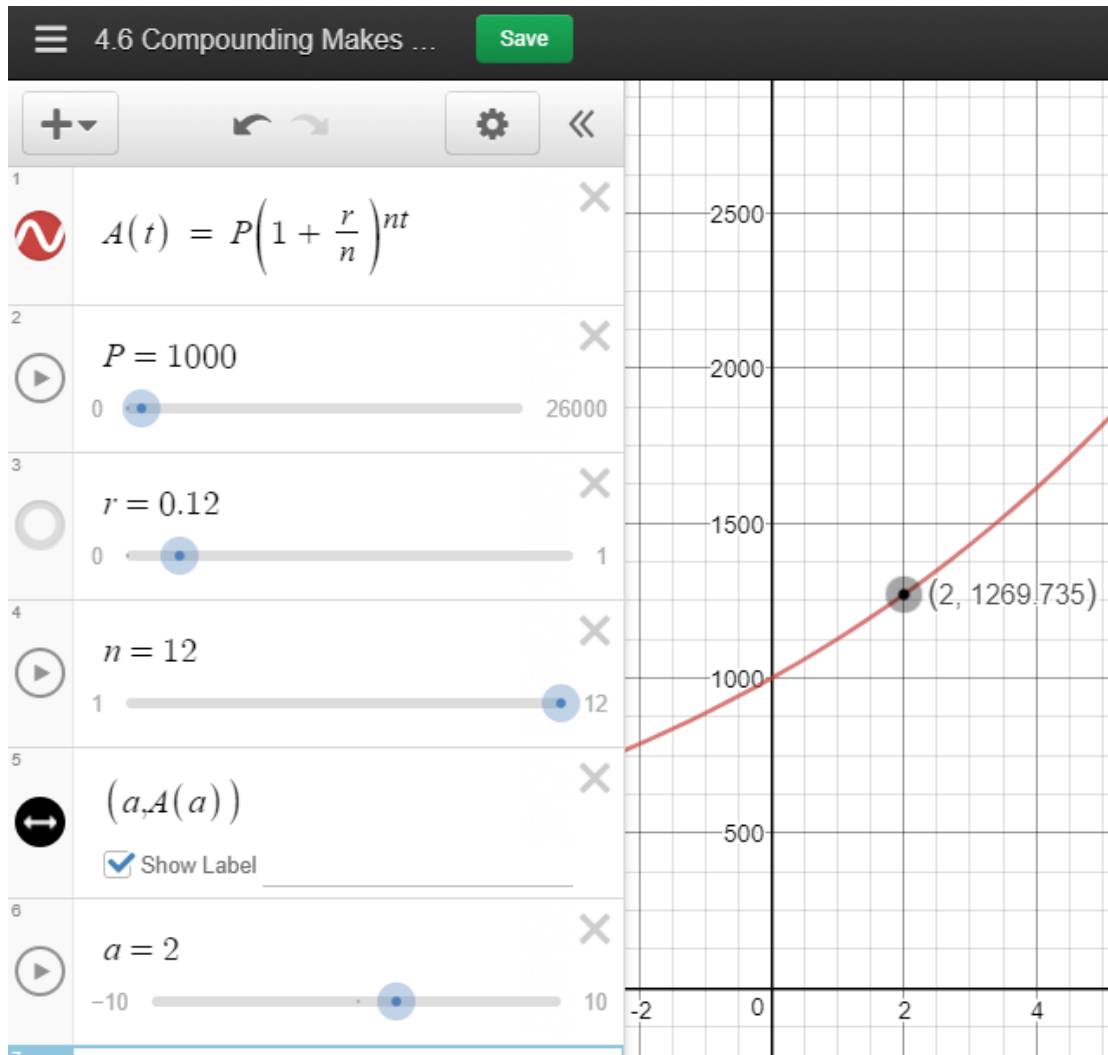


Figure 3.11

The students were also asked to write an exponential decay model that illustrates the depreciation of an automobile. The cost of the vehicle is \$26,000 and the depreciation rate is 15% each year. The students were asked to calculate the value of the car in 5 years. Each group was required to develop a model that illustrates this situation and then transfer the equation to Desmos for further analysis (Figure 3.12).

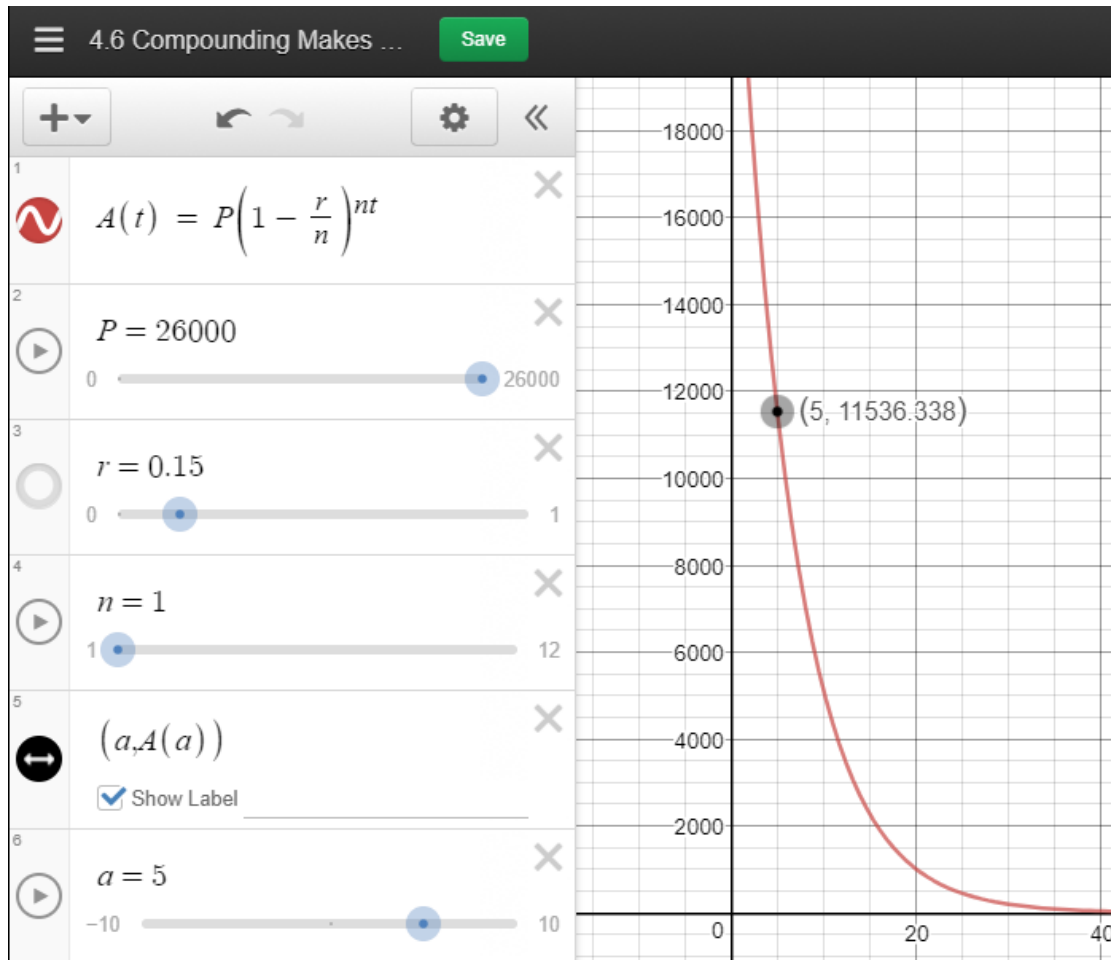


Figure 3.12

The last section that Group B used iPads, Desmos, and AirPlay on was for *4.8 Green Savings*. In this problem situation, the students were required to calculate the cost difference between two vehicles: a regular gas-powered Honda Civic and a Honda Civic hybrid. The specifics for each vehicle are:

- A 2014 Honda Civic hybrid costs \$24,635. This car is supposed to get 44 miles per gallon (mpg) in regular city driving and 47 mpg on the highway.
- A completely gas-powered 2014 Honda Civic costs \$18,390. This car is supposed to get 30 mpg in regular city driving and 39 mpg on the highway.

Before doing any calculations the students were asked to make predictions to the following two questions.

1. Will the extra cost for the hybrid be made up in the cost of gas by 100,000 miles?
2. How many miles would someone have to drive to make up the cost difference between the two vehicles?

The students were then asked to derive an equation that models each type of Civic. Then, they were instructed to transfer the equation they developed into Desmos for further exploration. The answer to the previous two questions are given on the graph in order pairs (Figure 3.13).

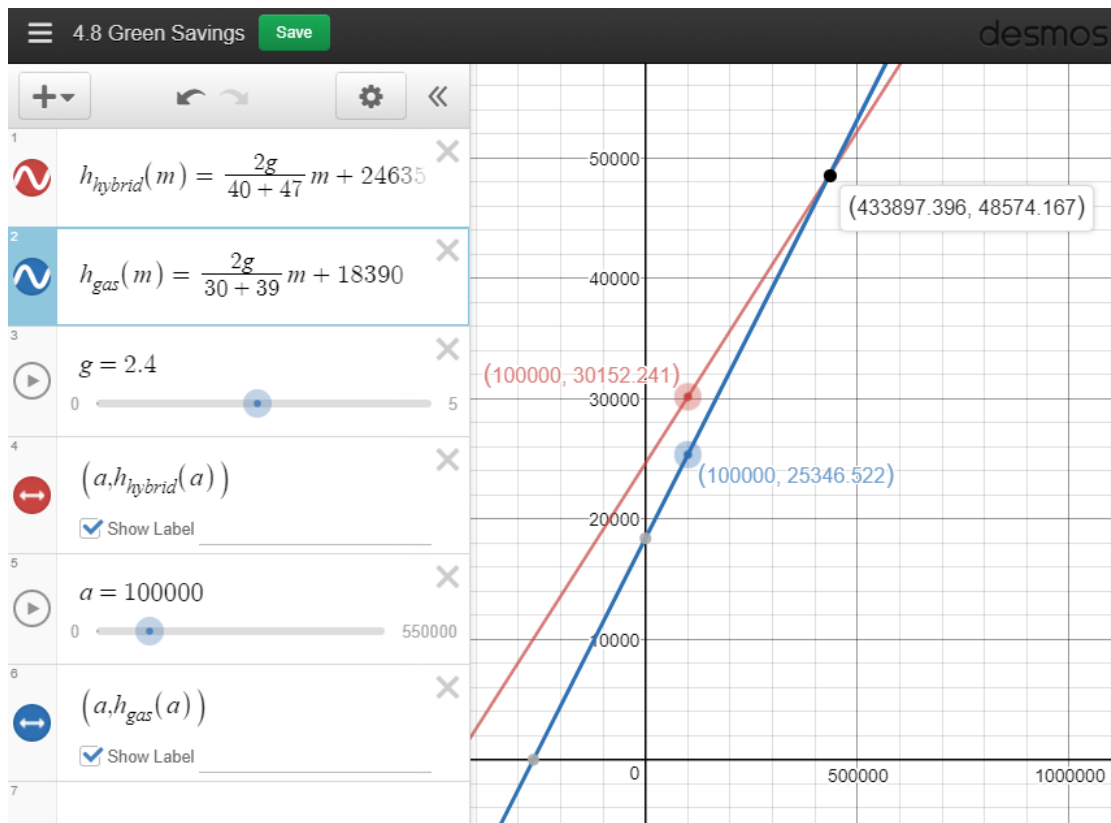


Figure 3.13

Throughout all four modules both groups worked out of the same workbook and had to answer the same questions. For Module 3 and 4 any graphing that was done by the control group was done by hand using a table of values and graph paper provided in the workbook. The

experimental group had the advantage of graphing in Desmos which enabled them to easily adjust parameters and experiment with in the program. At the end of Module 4, a test was given. The students in the experimental group (Group B) were allowed to use a calculator and Desmos on the Module 4 Test. The control group took the same test but was only allowed to use a calculator. The results of this test are detailed in Chapter 4 - Results.

Several factors will ultimately contribute to the outcome of this study. Uncontrollable factors that could affect the study are: attendance, class participation, engagement within groups, willingness to ask questions, motivation to seek help outside of class, individuals' previous experiences, and the group's overall aptitude for mathematics. Regardless of these uncontrollable factors, I believe the fundamental objective to increase students' understanding and retention through the use of iPads, Desmos, and Airplay is obtainable. The results of each group's average test scores from the four Module tests and final exam was then analyzed to check for any noticeable change in student performance.

### Chapter 4 - Results.

This study consisted of 33 college students from two different Mathematical Reasoning courses. The students for this study used ICTs (Information and Communication Technologies) that were integrated into a collaborative classroom using the Quantway Curriculum design by the Carnegie Institute. The intentions of this study were to have students utilize technology to deepen their overall understanding and retention of the material. This will be tested by answering five questions:

1. Did integrating ICTs into the experimental group's curriculum increase the mean score on the Module 3 Test?
2. Did integrating ICTs into the experimental group's curriculum increase the mean score on the Module 4 Test?
3. Was there a noticeable difference in the mean score on the final exam between the two groups?
4. Did students participating in this experiment have a higher mean test score when compared to the previous semester?
5. Did students participating in this experiment have a higher mean final exam score when compared to the previous semester?

For the remainder of this study, the two classes will be referred to as Group A (19 participants) and Group B (14 participants). I started my analysis by first doing a comparison of individual test scores between the two groups on all four Module tests and the final exam. Module 1 (Figure 4.1) and Module 2 (Figure 4.2) were analyzed to set a performance baseline standard between the two classes. For the Module 2 Test, Module 3 Test, and Module 4 Test, both groups were given the opportunity to answer two extra credit questions that covered two of

the main concepts from the previous semester. For each of these three Module tests the max score was 108%.

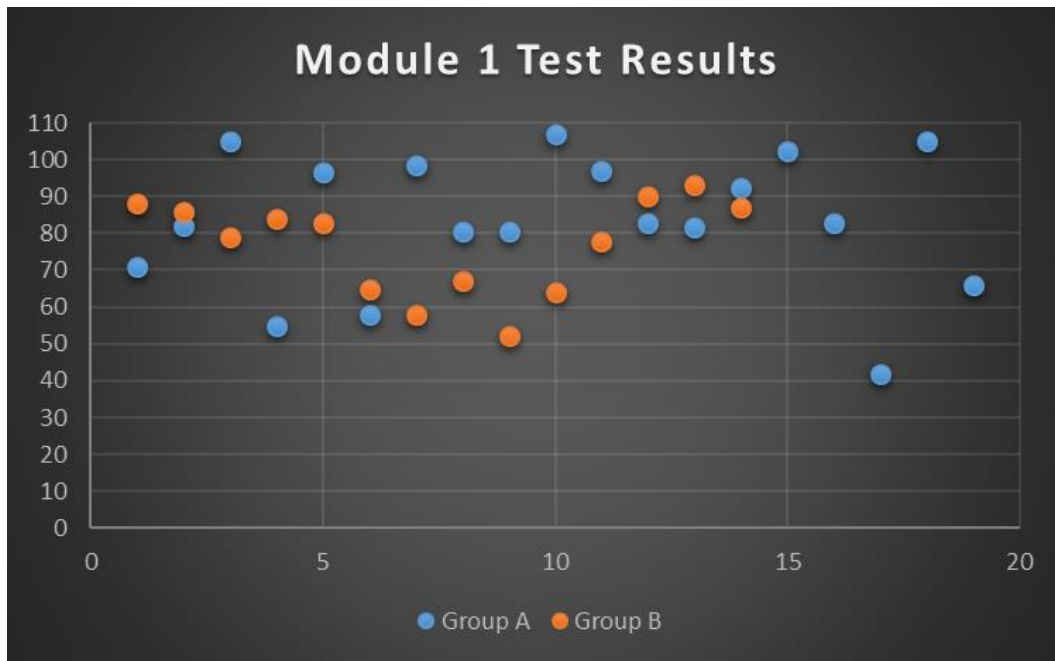


Figure 4.1

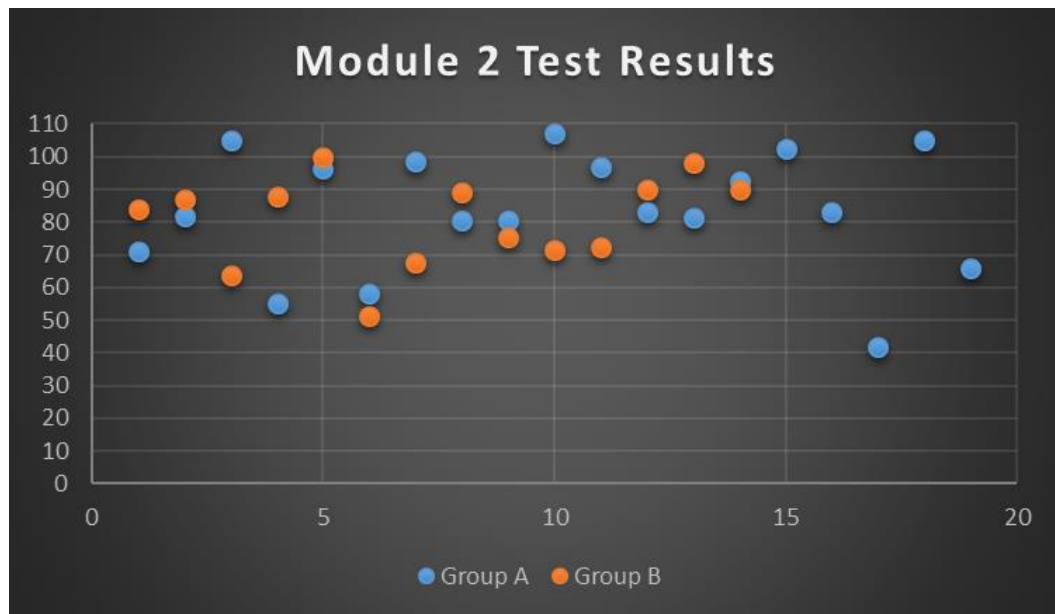


Figure 4.2

On the first two Module tests, neither class had been introduced to iPads, Desmos, or AirPlay. Figure 4.1 clearly shows that Group A outperformed Group B. Group A had a mean test score of 81.16% and a standard deviation of 16.86. Group B had a mean test score of 76.71% and a standard deviation of 13.05. The Module 1 difference in the mean test scores for the two groups was 4.44%. The Module 2 Test showed similar results with Group A outperforming Group B, with Group A having a mean test score of 83.5% and a standard deviation of 18.51 while Group B had a mean test score of 80.55% and a standard deviation 13.86. The mean test score difference between the two groups for Module 2 was only 2.95%. The analysis of the first two modules allowed me to set a baseline to gauge the performance levels for the Module 3 Test, Module 4 Test, and the final exam.

During the Module 3 implementation, students stated that they liked the iPads and Desmos. Several students claimed that the models helped them understand how changing certain parameters in an equation can have a small or huge effect on the results. The collaborative setting seemed to aid in the students' ability to interact with content and technology. If anyone did struggle with the calculations, iPads, or Desmos, there always seemed to be a student willing to help.

The initial analysis of the Module 3 results revealed a shift in performance. Group A had a considerable number of students who scored higher than Group B. The results of the individual test scores can be seen in Figure 4.3.

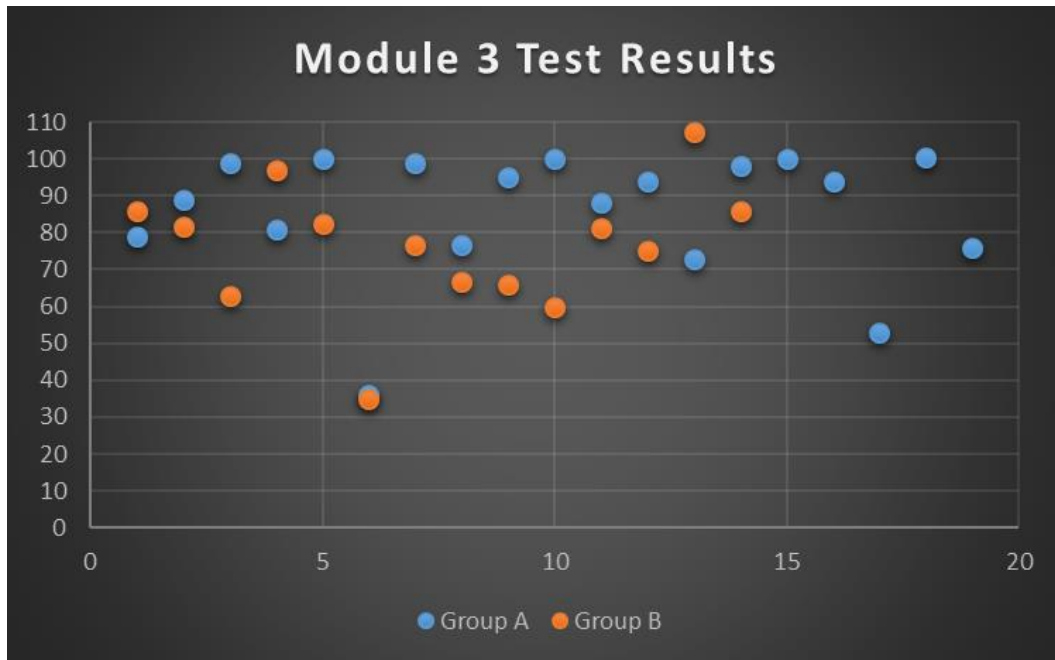


Figure 4.3

For Module 3, Group A had a mean test score of 85.83% and a standard deviation of 17.52 while Group B had a mean test score of 75.98% and a standard deviation of 17.57. The mean test score difference between the two groups for Module 3 was 9.85%. The results of the Module 3 analysis show a mean test score difference that is over twice as high compared to Module 1 and over three times higher than the mean test score difference of Module 2. The results from this section allow me to answer my first question: Did integrating ICTs into the experimental group's curriculum increase the mean score on the Module 3 Test?

Clearly something caused a change for Group A (experimental group) that put the mean test score almost a full letter grade higher than Group B (control group). I first considered any uncontrollable factors that could have an impact on the results between the two groups. The uncontrollable factors that I considered are class participation, engagement within groups, willingness to ask questions, motivation to seek help outside of class, individual's previous experiences, and the group's overall aptitude for mathematics. The only intended difference

between the two groups was the integration of ICTs into sections *3.1 Salary per Minute*, *3.2 The Cost of Driving*, *3.4 Braking Down the Variables*, and *3.6 Balancing Blood Alcohol*. This suggests that integration of ICTs can have a positive impact on students' understanding. The major difference going into Module 4 was Group A would become the control group while Group B would be the experimental group.

The results for Module 4 showed a shift in performance on the mean test scores. Group B (experimental group) for the first time outperformed Group A (control group). The individual test scores for the two groups are displayed in Figure 4.4. The mean test score for Group B was 80.89% with a standard deviation of 17.98, and Group A had a mean test score of 79.47% and a standard deviation of 24.53. Further investigation into the mean test scores for Group A revealed that there was one student who did not take the test and received a zero. After recalculating data without the zero for Group A, the mean test score changed to 83.89% and a standard deviation of 15.66.

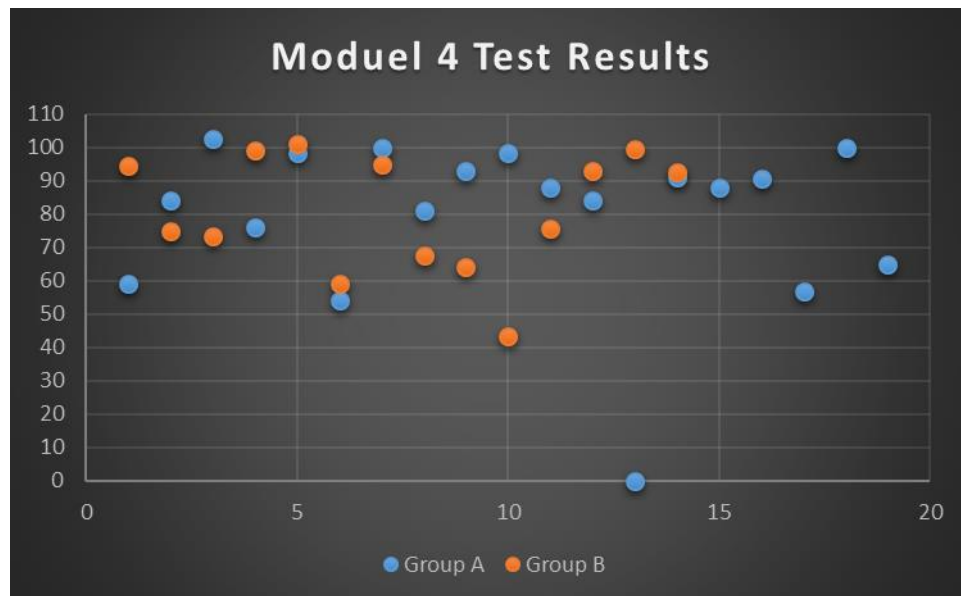


Figure 4.4

During the Module 4 implementation, the students in the experimental group valued how the iPads, Desmos, and AirPlay created a visual of the answers. They also liked the ability to be able to easily adjust values and see how the models changed simultaneously. Furthermore, the collaborative setting seemed to aid in the students having a positive and enthusiastic interaction with the iPads and Desmos. There always seemed to be a student willing to help other group members if someone was having difficulties with the technology. The analysis of Module 4 provided more questions than answers and left me with inconclusive evidence to answer my second question: Did integrating ICTs into the experimental group's curriculum increase the mean score on the Module 4 Test?

I ultimately came to two different conclusions: 1) Group B was successful in integrating ICTs and closed the achievement gap that was noticed during the Module 3 analysis or 2) since the mean test score difference was similar to Module 1 and Module 2, it is possible that Group A did not retain the information gained in Module 3. The next step was to analyze the results of the final exam and try to answer my third question: Was there a noticeable difference in the mean score on the final exam between the two groups? I would like to point out that both groups were allowed to use a scientific calculator on the final and neither group could use a graphing calculator or Desmos.

To answer question three I first plotted the individual final exam scores and provided those results in Figure 4.5.

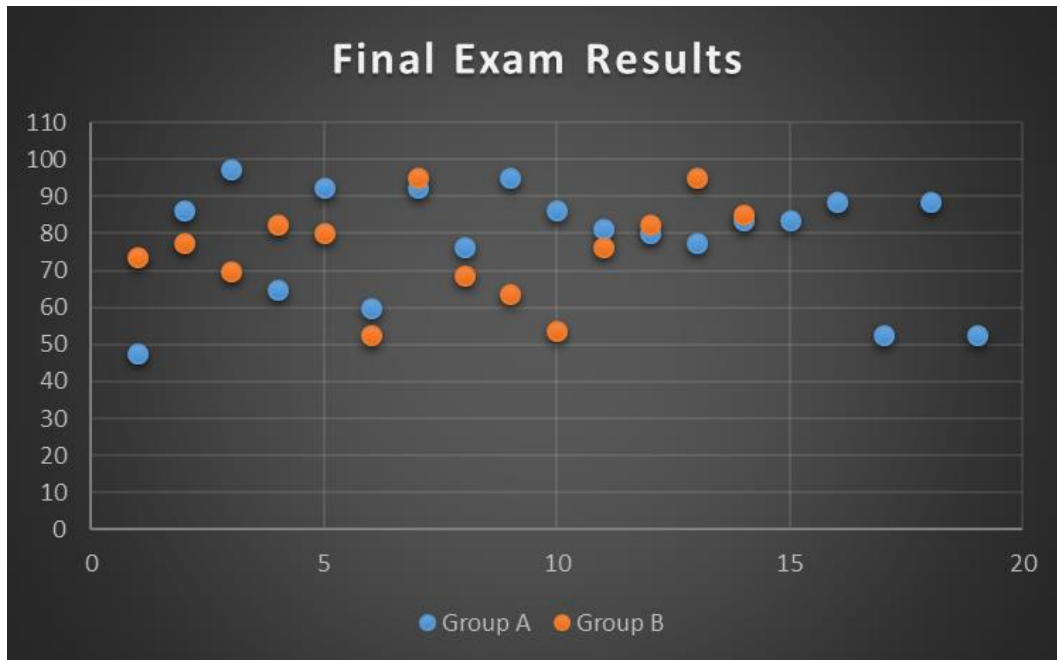


Figure 4.5

I then calculated the two groups' mean and standard deviation. Group A had a mean of 78.29% and standard deviation of 15.39 and Group B had a mean of 75.45% and standard deviation of 12.99. The results of the mean final exam scores were similar to the mean test results of Modules 1, 2, and 4. This time I was expecting the mean final exam scores to be close. Both groups had the opportunity to implement ICTs into the curriculum for their perspective module. To gain a better representation of the semester, I decided to put all the mean assessment scores in a clustered bar graph (Figure 4.6). The clustered bar graph gave me a general overview of the entire semester. I confirmed the results and conclusions I have made thus far: that for the entire semester there was a similar knowledge gap, with the exception of Module 3, between Group A and Group B. This gap can be attributed to several factors of which I think the main two would be the instructor teaching the course and the math experience that each student came in with. This led me to think about how this semester would compare to the previous semester.

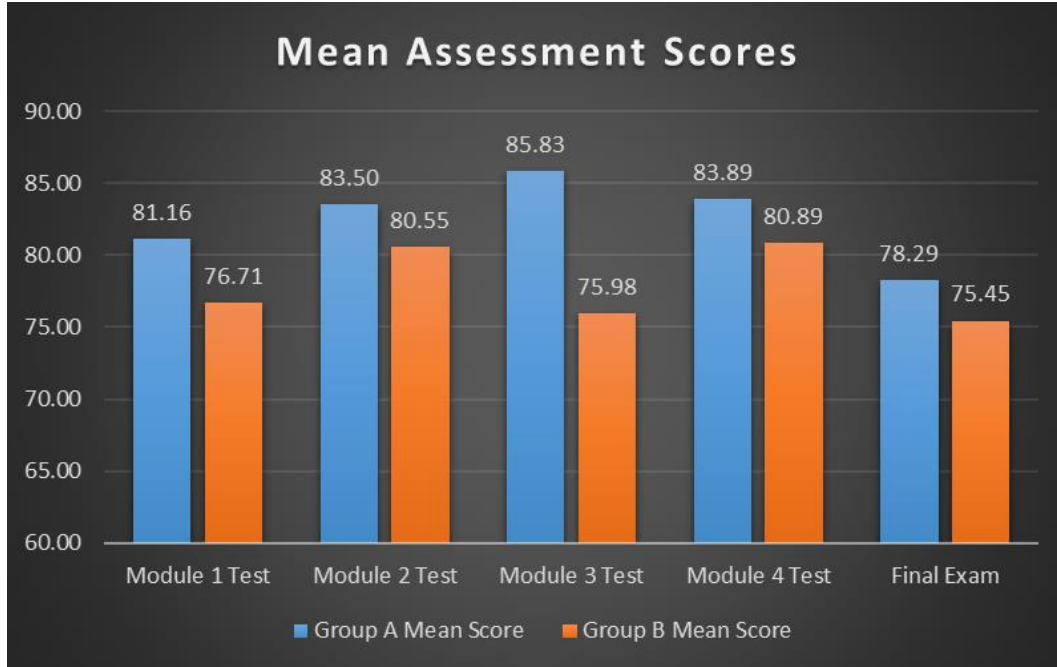


Figure 4.6

Mathematical Reasoning is a relatively new course for our technical college. So I was only able to compare this semester to the previous one. The results of doing so led me to answer my final two questions:

4. Did students participating in this experiment have a higher mean test score when compared to the previous semester?
5. Did students participating in this experiment have a higher mean final exam score when compared to the previous semester?

To show the results of the two different semesters, I used another clustered bar graph. For the comparison of these two groups, I will refer to the fall class as the control group and the spring class as the experimental group. Both semesters used the same Quantway textbook and workbook from the Carnegie Institute. It is important to note that the fall class did not have ICTs

integrated into any of the modules throughout the semester and took the same assessments. The spring class was the first to have ICTs implemented into the curriculum. The results for the two semesters are provided in Figure 4.7.

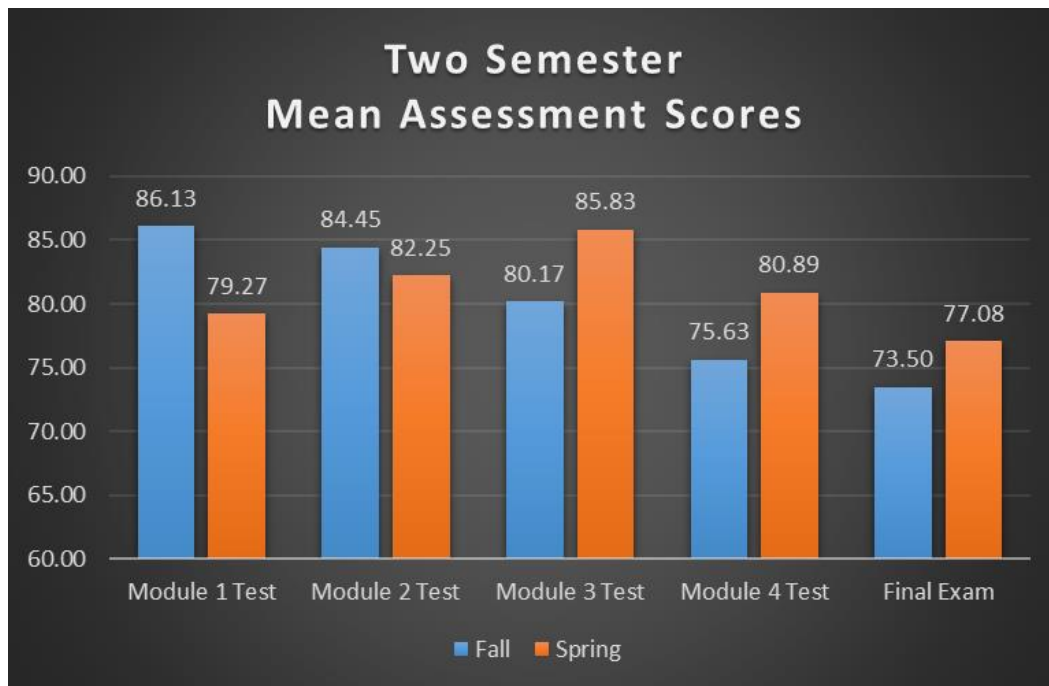


Figure 4.7

Figure 4.7 clearly indicates a noticeable change in the mean assessment scores for the two semesters between Module 2 and Module 3. During Module 1 and Module 2, the control group outperformed the experimental group. After Module 2, the experimental group outperformed the control group and did so for the remainder of the course. The experimental group outperformed the control group on both the Module 3 Test and Module 4 Test by over 5% and outperformed them on the final by 3.5%. These results support that integrating ICTs in our Mathematical Reasoning curriculum could be a factor in influencing growth in student performance. The intentions of this study were to have students utilize technology to deepen their

overall understand and retention of the material. This might have been accomplished by integrating ICTs (Information and Communication Technologies) in a collaborative classroom using the Quantway Curriculum design by the Carnegie Institute. Moving forward, I believe that future studies and data should be collected to add to the validity of this study.

### Chapter 5 - Reflection

My motivation to do this project was to find a way to make mathematics more engaging and interactive while integrating 21<sup>st</sup> century technology into the classroom. My main goal was to utilize technology like iPads and Desmos to deepen students' overall understanding and retention of the mathematical concepts. When comparing the mean assessment scores of the fall (control group) and spring (experimental group) semester you could clearly see a performance growth that was not present in the first two modules. I attribute this success to the integration of ICT's (Information and Communication Technologies).

When doing my initial analysis of the data between the two groups that took part in the ICT integration, I started to feel a little skeptical. The Module 3 results showed a performance gap increase of two times that of Module 1 and three times that of Module 2. This initial examination showed promise that ICTs were having a positive impact on the students' performance. But, when the data was analyzed for Module 4 the information was inconclusive and resulted in one of two conclusions: 1) the experimental group closed the performance gap which would support the positive impact that ICTs can have or 2) the control group was not able to retain the information learned from the previous module which put the performance gap similar to the first two modules. I wanted a way to solidify one of the two conclusions for the results of Module 4. I decided to start doing a comparison of mean assessment scores from the previous semester. The previous semester was a fall class that was taught by myself. The fall students worked primarily out of the textbook and workbook and did not use ICTs within the curriculum. Both semesters were given the same Module tests and were only allowed to use a scientific calculator on the final exam.

The data analysis of the two different semesters showed evidence to support that ICT integration can have a positive impact on students. Both semesters were given the same Module tests and the same final exam. The comparison of the mean assessment scores are as follows:

Two Semester Mean Assessment Scores			
	Spring Semester	Fall Semester	Difference
Module 1	79.27%	86.13%	-6.86%
Module 2	82.25%	84.45%	-2.20%
Module 3	85.83%	80.17%	5.66%
Module 4	80.89%	75.63%	5.26%
Final Exam	77.08%	73.50%	3.58%

Figure 5.1

From Figure 5.1 you can see how the spring semester group was outperformed by the fall semester group on the first two modules. During the Module 3 comparison (only the mean assessment score from Group A in the initial study was used) the spring semester group outperformed the fall semester group by more than half a letter grade. Once again the data for the Module 3 test supported the initial claim that ICTs will increase students' understanding of the content and improve test scores. When looking at the Module 4 test I found a similar result. The spring group (only the mean assessment score from Group B in the initial study was used) outperformed the fall group yet again and by more than half a letter grade. The last analysis that I did was to compare the final exam between these two groups. The spring semester group outperformed the fall semester group for the third time. Although the difference was only a third of a letter grade I believe this still provides evidence to support the positive effects that ICTs can have in a math curriculum. I believe the results of the mean assessment scores for the fall and spring groups on the Module 3 Test, Module 4 Test, and the final exam shows evidence that ICTs could improve student comprehension and understanding. For this reason alone I think as educators we should start to make a transition of integrating 21<sup>st</sup> century ICTs into are math curriculums.

Another motivating factor for this study was my desire to increase student engagement while increasing understanding of the competencies in this course. I was overwhelmed by the students' interaction with each other and the discussions that took place when analyzing graphs on Desmos. Desmos gave the students the ability to modify the graphs and immediately answer investigative questions that were not originally asked in the lesson. I also believe being able to link the iPads and broadcast the real-time images played an important role. When students were developing their models, oftentimes other groups would interact with each other. Groups would share input methods with each other that oftentimes enhanced a graph's functionality and comprehension.

Towards the end of the semester I asked students what they thought of the class' particularly the curriculum, collaborative classroom setting, and the iPad and Desmos integration. Below are some comments from the students.

*I really liked this class it was completely different than a normal math class.*

*I think using the iPads is fun and I understand the stuff better too.*

*This is a great class! I like that we talk through the problem and can help each other out.*

Then I had a student that made a comment that I still think about. He said, "I have never talked this much in a class." I made a point to clarify to the class that he meant he has never talked this much in a math class. He then said, "No, I have never talked this much in any class in high school or college." As I thought more about his statement I started to realize that the real learning and magic of teaching does not happen when I'm lecturing. The real learning starts when students are engaged and interacting with one and other. I believe that ICTs open up that kind of interaction. We are teaching to 21<sup>st</sup> century students. It is time for us to leap forward and start using 21<sup>st</sup> century technology.

### **Recommendations for Future Study**

In a future study, I would like to increase the number of participants and implement the ICT's throughout the entire semester. This study would include a pretest to set a base line between the experimental and control groups. I could then compare the test results from both groups for all four modules. The study would conclude with a posttest or final exam.

Another study could be done with an additional criterion that would look for student engagement and attendance. In this study I would include a scale that has the ability to quantify student engagement. By doing so, educators could potentially identify barriers to student participation and implement procedures to increase student involvement and learning. As part of the engagement portion, I would also include daily attendance. I am a strong believer that attendance will increase if students are actively learning and engaged in the material.

I think regardless of the study anyone is doing, it is important to focus on how we can improve education. One way to make this improvement is for educators to push the barriers and resist falling into the education norms. With so many students underperforming and underprepared for college it is time to realize the norm is not working. ICTs are just one way that educators can find a newer method of engaging our students. I am not saying that ICTs are the definitive answer, but I do think initiatives like this are a step in the right direction.

## Chapter 6 - References

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**Appendix A – Figures**

Figure 2.1. Salamis Abacus. Retrieved from: <https://www.abacus-maths.com/files/Greek%20Abacus.png>

Figure 2.2. Cal Tech Calculator. Retrieved from: <http://newscenter.ti.com/download/photos+960+hi.jpg>

Figure 2.3. Ingraham, M. (2013). Incorporating iPad Technology into the Classroom: A Geometry Project. *Ohio Journal Of School Mathematics*, (67), 27-32.

Figure 3.1. Desmos model of 3.1 Salary per Minute Question 1 Retrieved from: <https://www.desmos.com/calculator/dv3qqhki6b>

Figure 3.2. Desmos model of 3.1 Salary per Minute Question 3 Retrieved from: <https://www.desmos.com/calculator/dv3qqhki6b>

Figure 3.3. Desmos model of 3.1 Salary per Minute Question 5 Retrieved from: <https://www.desmos.com/calculator/cn1swizgxi>

Figure 3.4. Desmos model of 3.2 The Cost of Driving Retrieved from: <https://www.desmos.com/calculator/aax2mlidiu>

Figure 3.5. Illustration of ruler test to calculate reaction time Retrieved from: <https://goo.gl/images/KSNoCW>

Figure 3.6. Illustration of question 3 results from 3.4 Desmos analysis Retrieved from: <https://www.desmos.com/calculator/tld5jjb8de>

Figure 3.7. Illustration of question 4 results from 3.4 Desmos analysis Retrieved from: <https://www.desmos.com/calculator/aell1anq2ry>

Figure 3.8. Illustration of 3.6 Desmos analysis Retrieved from: <https://www.desmos.com/calculator/bxv9rpcvdh>

Figure 3.9. Illustration of 4.2 Desmos analysis Retrieved from:

<https://www.desmos.com/calculator/xhimmmqcjg>

Figure 3.10. Illustration of 4.5 Desmos analysis Retrieved from:

<https://www.desmos.com/calculator/xy6blik26u>

Figure 3.11. Illustration of 4.6 Desmos analysis Retrieved from:

<https://www.desmos.com/calculator/uztjzmidae>

Figure 3.12. Illustration of 4.6 Desmos analysis Retrieved from:

<https://www.desmos.com/calculator/xvx64ut4e1>

Figure 3.13. Illustration of 4.8 Desmos analysis Retrieved from:

<https://www.desmos.com/calculator/hlf0mckr7j>

Figure 4.1. Scatter Plot of the Module 1 Test Results exported from excel

Figure 4.2. Scatter Plot of the Module 2 Test Results exported from excel

Figure 4.3. Scatter Plot of the Module 3 Test Results exported from excel

Figure 4.4. Scatter Plot of the Module 4 Test Results exported from excel

Figure 4.5. Scatter Plot of the Final Exam Results exported from excel

Figure 4.6 Clustered Bar Graph of the Mean Assessment Scores exported from excel

Figure 4.7 Clustered Bar Graph of the Two Semester Mean Assessment Scores exported from

excel

## Appendix B – Curriculum Timeline.

### Module 3 - Week 8

Day 1

Lecture	ICE 2.8 Has Minimum Wage Kept Up
HW	OCE 2.8

Day 2

Lecture	Module 2 Review and Module 2 Checkpoint
HW	Module 2 Checkpoint

Day 3

Lecture	Module 2 Test (20 problems)
HW	PNL 3.1 pp 279-284

Day 4

Lecture	Introduce the concept and methodology of dimensional analysis – lead class through question 1, small groups for question 2 & 3 pp 315-317
<b>Desmos</b>	<b>Desmos model illustrating linear model for driving distance, given mpg and quantity of gas in gallons.</b>
HW	Start working on OCE 3.1 pp 319-321

### Module 3 - Week 9

Day 1-Desmos Activity

Lecture	ICE 3.1 Salary per Minute Questions 4-6 and Making Connections pp 317-318
HW	OCE 3.1 pp 319-321
HW	PNL 3.2 p 323

Day 2

Lecture	ICE 3.2 The Cost of Driving, Part 1 pp 325-327
<b>Desmos</b>	<b>Desmos model illustrating linear model for driving distance, given velocity and the time it takes to read and respond to a text message.</b>
HW	Start working on OCE 3.2 pp 333-335

Day 3

Lecture	ICE 3.2 The Cost of Driving, Part 2 pp 328-331
HW	OCE 3.2 pp 333-335
HW	PNL 3.3 pp 337-341

Day 4

Lecture	ICE 3.3 The Fixer Upper pp 343-346
HW	Start working on OCE 3.3 pp 347-349

### Module 3 - Week 10

## Day 1

Lecture	ICE 3.3 The Fixer Upper pp 343-346
HW	OCE 3.3 pp 347-349
HW	PNL 3.4 pp 351-352

## Day 2

Lecture	ICE 3.4 Breaking Down Variables (Formulas and Applications) pp 353-356
HW	Start OCE 3.4 pp 357-362

## Day 3

Lecture	ICE 3.4 Breaking Down Variables (Formulas and Applications) pp 353-356
<b>Desmos</b>	<i>Desmos image with average ruler length of six inches.</i> <i>Desmos image with average ruler length of twelve inches.</i> <i>Desmos image with a velocity of 25 mph.</i> <i>Desmos image with a velocity of 50 mph.</i>
HW	OCE 3.4 pp 357-362
HW	PNL 3.6 pp 375-378

## Day 4

Lecture	ICE 3.6 Balancing Blood Alcohol pp 379-382
HW	Start OCE 3.6 pp 383-387

**Module 3 - Week 11**

## Day 1

Lecture	ICE 3.6 Balancing Blood Alcohol pp 379-382
<b>Desmos</b>	<b>Desmos image for modeling the BAC as a function of time.</b>
HW	OCE 3.6 pp 383-387
HW	PNL 3.7 pp 389-391

## Day 2

Lecture	ICE 3.7 A Return to Proportional Reasoning pp 393-396
HW	OCE 3.7 pp 397-403
HW	PNL 3.8 pp 405-407

## Day 3

Lecture	ICE 3.8 Solving More Equations pp 409-412
HW	Start OCE 3.8 pp 413-416

## Day 4

Lecture	ICE 3.8 Solving More Equations pp 409-412
HW	OCE 3.8 pp 413-416

**Module 3 - Week 12**

## Day 1

Lecture	Module 3 Checkpoint and Review for Module 3 Test pp 421-422
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HW	Module 3 Checkpoint
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Day 2

Lecture	Module 3 Test
HW	PNL 4.1 pp 417-419

### Module 4 - Week 12

Day 1

Lecture	Module 3 Checkpoint and Review for Module 3 Test pp 421-422
HW	Module 3 Checkpoint

Day 2

Lecture	Module 3 Test
HW	PNL 4.1 pp 417-419

Day 3

Lecture	ICE 4.1 Lining Up pp 425-431
HW	OCE 4.1 pp 433-440
HW	PNL 4.2 pp 441-442

Day 4

Lecture	Go over results of Module 3 Test
Lecture	ICE 4.2 – Comparing Change Building linear models to estimate soda and milk consumption over time. pp 443-448
<b>Desmos</b>	<b>Desmos image for Comparing Change.</b>
HW	Start OCE 4.2 pp 449-453

### Module 4 - Week 13

Day 1

Lecture	ICE 4.2 – Comparing Change pp 443-448
HW	OCE 4.2 pp 449-453
HW	PNL 4.3 pp 455-458

Day 2

Lecture	ICE 4.3 – That is Close Enough Creating linear models from data pp 459-463
HW	Start OCE 4.3 pp 465-472

Day 3

Lecture	ICE 4.3 – That is Close Enough pp 459-463
HW	OCE 4.3 pp 465-472
HW	PNL 4.4 pp 473-476

**Module 4 - Week 14**

## Day 1

Lecture	ICE 4.4 – The Cost of Business pp 477-480
HW	Start OCE 4.4 pp 481-486

## Day 2

Lecture	ICE 4.4 – The Cost of Business pp 477-480
HW	OCE 4.4 pp 481-486
HW	PNL 4.5 pp 487-488

## Day 3

Lecture	ICE 4.5 Compounding Interest Makes Cents Intro to exponential models pp 489-492
<b>Desmos</b>	<b>Desmos image for Compounding Interest Makes Cents.</b>
HW	Start OCE 4.5 pp 493-497

## Day 4

Lecture	ICE 4.5 Compounding Interest Makes Cents Intro to exponential models pp 489-492
HW	OCE 4.5 pp 493-497
HW	PNL 4.6 p 499

**Module 4 - Week 15**

## Day 1

Lecture	ICE 4.6 Compounding Makes More Cents & Exponential functions pp 501-504
HW	Start OCE 4.6 pp 505-508

## Day 2

Lecture	ICE 4.6 Compounding Makes More Cents & Exponential functions pp 501-504
<b>Desmos</b>	<b>Desmos image for Compounding Makes More Cents.</b>
HW	OCE 4.6 pp 505-508
HW	PNL 4.7 pp 509-510

## Day 3

Lecture	ICE 4.7 Short Term Loans-Exponential and Linear Models pp 511-514
HW	OCE 4.7 pp 514-522
HW	PNL 4.8 pp 523-525

## Day 4

Lecture	ICE 4.8 Green Savings-Linear Modeling pp 527-530
<b>Desmos</b>	<b>Desmos image for Green Savings.</b>
HW	OCE 4.8 pp 531-532 (optional assignment)

**Module 4 - Week 16**

## Day 1

Lecture	Review for Module 4 Exam pp 545-546
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HW	Module 4 Checkpoint (enter answers into Canvas)
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Day 2

Lecture	Module 4 Exam
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Day 3

Lecture	Final Exam Review pp 547-552
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Day 4

Lecture	Final Exam
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