SOLVING SYSTEMS OF LINEAR EQUATIONS: AN ELEARNING MODULE
FOR 9TH GRADERS

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ABSTRACT

One of the common core state standards for high school mathematics relates to the topic of solving systems of equations. This paper will discuss the steps that were taken to create and test a web-based eLearning Module. Systems of linear equations are often confusing for students in the 9th grade since it is the first time they encounter manipulating two functions to solve two variables (Cai, Nie, & Moyer, 2010). Use of graphing software can help students see the relationship between two linear functions for determining what they have in common. Additionally, the use of eLearning modules can keep students on track with these kinds of assignments (Lynch & Kim, 2017; Witte, Haelermans, & Rogge, 2014).

The purpose of this project was to create a web-based, eLearning module to teach 9th grade high school students how to solve systems of linear equations algebraically and graphically.

The instructional designer used the ADDIE instructional design model as a guide to create this project. ADDIE is an acronym for Analysis, Design, Development, Implementation, and Evaluation. Each phase of the ADDIE model builds on the previous steps to help create material that can be used to successfully teach needed skills (Molenda, 2015). The content covered in this project was the four ways to solve systems of linear equations. This project is an eLearning Module for students to learn systems of linear equations and multiple ways they could be solved. This Project contains videos, pictures and interactive
multimedia elements for the learner to practice. Storyline Articulate 3 and Articulate Replay were used in the construction of this project.

The field testing was conducted in a California High School. Twenty-eight ninth-grade students were invited to voluntarily participate in a field testing. Fourteen of those students completed the project and answered the survey questions. The study involved students going to web-based, eLearning module to learn how to solve systems of linear equations algebraically and graphically. The eLearning module contained multimedia elements such as videos and other interactive elements. At the end of the project there was an anonymous survey with ten questions that asked the students about their overall opinion, perception and interaction with the project.

There was an overall positive feedback given about the eLearning module. Participants were able to navigate through the pages watch the instructional videos and respond to interactive quizzes as well as learn about systems of linear equations and the four ways of solving them. Students who participated preferred learning from an interactive eLearning module than learning from a textbook or a traditional lecture.
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CHAPTER ONE

INTRODUCTION

One of the common core state standards for high school mathematics relates to the topic of solving systems of equations. These standards put emphasis on the study of linear functions and their importance for understanding basic algebra (Pierce, Stacey, & Bardini, 2010). Systems of linear equations are often confusing for students in the 9th grade since it is the first time they encounter manipulating two functions to solve two variables (Cai, Nie, & Moyer, 2010).

Teachers are using technology in the classroom to assist in the learning process. Students are more likely to work on mathematics at home if they have access to different resources such as videos. Use of graphing software can help students see the relationship between two linear functions for determining what they have in common. Additionally, the use of eLearning modules can keep students on track with these kinds of assignments (Lynch & Kim, 2017; Witte, Haelermans, & Rogge, 2014).

Background of the Problem

The teachers in the education system want to make sure that the younger generation is prepared with the skills they need to succeed in life. The Common Core State Standards were created to assure that students acquired the same skills and competencies despite where they attended school (Van Tassel-Baska, 2015).
Multiple options are available to solve mathematic problems. Systems of linear equations are solved using four main strategies taught in the classroom: 1) graph each equation and see where the lines intersect on a graph, 2) set both equations equal to each other, 3) substitute one equation into the other and 4) multiply the equation so that a coefficient can be canceled out. It is important that students understand how to use each method (Fonger, Davis, & Rohwer, 2018).

Often teachers teach the way they were taught, and the introduction of math-assisting technology is relatively new in the classroom. Teachers are encouraged to use new methods to teach material in the classroom and digital technology is at the forefront (White-Clark, DiCarlo, & Gilchriest, 2008). Scaffolding this material plays an important role in the learning process. Students who do not receive continuous reinforcement end up forgetting what they have learned. It takes a considerable amount of time and effort on the parts of teachers to stay informed on what each student knows and what needs to be reviewed. They must make sure that a student remembers that there are multiple ways to solve a single mathematical problem and that each method requires specific steps (Moschkovich, 2015). During scaffolding, students need a chance to practice what they have learned. Giving questions with feedback allows students to learn from their mistakes and not make the same mistake (Edson, 2017).

Through eLearning lessons, students independently explore the educational materials they are learning at their own pace. Unfortunately, it is easy for the learner to get distracted from what they should be learning (Witte, 2019).
Nevertheless, the flipped classroom method is being used more regularly in school. It focuses on giving the students the lesson at home so they can work on it by themselves, and when they attend class prepared, they are able to ask relevant questions. In most cases, this flipped method uses technology that is designed by the teacher or a developer. Pre-recorded videos embedded in the eLesson allow students to work on their own (Cargile & Harkness, 2015; Schmid & Ralph, 2016). The research shows that students who have access to technology and additional resources at home are more likely to study and do better in school. TenMarks, Khan Academy and other online resources are often used when using the flipped classroom method (Lynch & Kim, 2017).

With computer aided assistance, students are able to start relying more on technology for assistance than people. If a mistake is made when solving a problem, additional resources such as hints are provided to assist students figure out the correct answer (Greenhow, 2015).

Pivotal teaching moments are an important aspect of learning. To ensure a pivotal teaching moment, it is important to test the learner’s content absorption. When there is confirmation that the learner understands what is being taught, higher level questions can be asked of the learner to continue the transfer of knowledge (Cayton, Hollebrands, Okumuş, & Boehm, 2017).
Statement of the Problem

To solve systems of linear equations, students must use two linear equations in the form of $y=mx+b$, both containing two variables (Cai, Nie, & Moyer, 2010). Unfortunately, 9th grade students often lack the ability to manipulate equations, making it difficult to solve abstract math in multiple ways (Huntley, Marcus, Kahan, & Miller, 2007).

Students spend a lot of time learning how to solve equations with one variable, as well as equations with two variables. Confusion starts when they start learning about systems of equations, where each one has two variables. Students need to understand that sometimes there will be no answer (parallel lines). Some students think that the intersection of the “x” and “y” axes is the answer to the variables. The degree of confusion varies depending on the students understanding of how linear equations should be interpreted visually and algebraically (Fonger, Davis, & Rohwer, 2018).

Students often lack the ability to solve more complex equations when several steps are involved. They also have difficulty describing an equation, forgetting fundamental math terminology and rules that apply to all mathematical equations (Adu-Gyamfi, Bossé, & Chandler, 2015).

Lee and Chen (2014) found that students who used technology-based manipulatives scored significantly higher than those who used physical manipulatives. There needs to be proper scaffolding of information so that students with low prior knowledge can take advantage of electronic manipulatives. According to Lee and Chen (2014) “students with high prior
knowledge, the post-test performance of the virtual manipulatives group was superior to that of the physical manipulatives group” (p. 191).

Often students are getting into these courses without proper preparation. Scaffolding has a critical role when it comes to mathematics. Students have to learn a large amount of information before they continue to a higher math class. Forgetting even one concept in math will affect their performance in learning the next concepts. Creating online resources for students helps them be more prepared for learning the next topics (Moschkovich, 2015; Edson, 2017).

**Purpose of the Project**

The purpose of this project was to create a web-based, eLearning module to teach 9th grade high school students how to solve systems of linear equations algebraically and graphically. This project was designed for students to work through the materials individually, practice at their own pace, and get self-feedback on how well they are performing.

This project was created based on the Common Core State Standards using the Articulate Storyline 3. The project focused on two specific standards. Videos were embedded in the project to reinforce the steps to be learned.

**Assumptions**

For this project the following assumptions were made:

- Student skill levels in mathematics varies.
- Students have access to computers connected to the internet.
- Students have the technical skills to navigate an eLearning tutorial.
- Students know how to graph equations using the point slope $y=mx+b$. 
• Students know how to substitute and solve multi-step equations.
• Students know how to manipulate an equation to create an opposite coefficient.
• Students are able to access this project on a smartphone or laptop.

Limitations

The following limitations affected the scope of this project:

• This project was limited to 9th grade high school freshman taking math 1.
• This project was limited to the duration of one day in class.
• This Project focused primarily on the Reasoning with Equations and Inequalities, Solving systems of equations standards [Linear-linear and linear-quadratic] : a-b

Definitions of Terms

Cartesian Plane

A rectangular coordinate system that associates each point on the plane with an ordered pair of real numbers. Individual points can be identified using the notation (x, y), where “x” refers to the “x” value on the horizontal axis and “y” refers to the “y” value on the vertical axis (Statistics Dictionary, 2019, p. 1).

Common Core State Standards (CCSS)

Common Core State Standards are defined as a set of common standards across the grade levels that identify the preparation level of students in
different content areas to succeed in college or in the work field (California Common Core State Standards, 2013).

**eLearning**

Using electronic applications and processes to learn, where contents are delivered via internet, intranet, extranet, satellite TV, CD-ROM with multimedia capabilities, etc. The applications and processes include web-based learning, computer-based learning, virtual classrooms and digital collaboration. Further, eLearning is defined as the individualized instruction delivered over public or private computer networks (Priya, Chandrakumarmangalam, & Arthi, 2015, p. 332).

**Flipped Classroom**

Flipped classroom is defined as using short video lectures that students watch at home so they come to class more prepared to get assistance with their questions, which is the opposite of what happens in traditional teaching (Schmidt & Ralph, 2016).

**Khan Academy**

Khan Academy is an online math website in which students are able to watch videos and work on computer generated problems based on those videos (Cargile & Harkness, 2015).

**Linear Equation**

Also known as a linear function, which is an equation for a straight line that can be graphed on the Cartesian plane (Pierce, 2018).
**Storyline Articulate 3**

A software that is used to create multimedia content that is used to teach the learner by interaction with the presentation. This software has the ability to input multimedia, present questions and offer feedback (Storyline 3, 2018).

**Systems of Linear Equations**

To see how two or more linear equations containing two variables interact with each other (Pierce, 2019; Stapel, 2014).

**Variable**

A symbol for a number that is not known. It is usually a letter like “x” or “y” (Pierce, 2018).
CHAPTER TWO

REVIEW OF LITERATURE

The purpose of this project was to create a web-based, eLearning module to teach 9th grade high school students how to solve systems of linear equations algebraically and graphically.

This literature review examines the California Common Core State Standards for Mathematics focused on specific standards for solving systems of linear equations in a 9th grade classroom. These standards also address difficulties that students face when solving linear equations, as well as, strategies that help clarify new information. The beneficial role of technology will also be examined in relation to its impacts on student achievement of the mathematic standards.

California State Standards for Ninth Grade Mathematics

Content standards are an important part of the school structure regardless of subject area. They help identify and organize academic content. These standards are for all main subjects such as Math, English, Science, History, as well as the newer subjects such as Computer Science (California Department of Education, 2017a).

Common Core State Standards are developed so that every state is teaching the same required content at a specific grade level. Common Core is the second attempt to reorganize the standards since the 1980s. The purpose is to raise the bar so students are prepared for the competitive employment market by having the necessary job skills. The standards focus on encouraging
discussion, critical thinking, problem-based learning, and asking the right questions (Van Tassel-Baska, 2015). According to Lovett and Lee (2017), most states have already adopted common core, which requires teachers to modify their lesson plans to align with these newer standards (Lovett & Lee, 2017). The digital literacy and technology skills to support the California Common Core state mathematics standards focus more on students in grades 6th–12th, while English Arts standards focus on grades K-5th (California Department of Education, 2017c).

The California Department of Education explains, “Information regarding what all students in California public schools should know and be able to do in mathematics, emphasizing computational and procedural skills, conceptual understanding, and problem solving” (California Department of Education, 2017b, p.1).

Nagy (2013) believes that it is important to have a strong understanding of mathematics to succeed in the future. This includes having the basic algebraic skills to succeed in a college math class (Nagy, 2013). This claim is further fortified by the conclusions drawn by Kilpatrick, Swafford, and Findell (2001) that state algebra is the path to more advanced mathematics, but can also be a roadblock for students who have difficulty in this subject. Even though algebra is an important subject taught in school, it can be confusing at times for students to grasp the content (Huntley, Marcus, Kahan & Miller, 2007). Teachers and researchers need to come up with strategies to help develop new ways to introduce mathematical information to prepare students for success (Kilpatrick,
Swafford, & Findell, 2001). Knuth (2000) observed that students do not have the basic mathematics skills to make connections between linear equations and their graphs. He also found that this partially stems from a lack of understanding of the different ways linear equations can be set up, such as point-slope or standard form (Knuth, 2000). Dubinsky explains that for a person to understand modern mathematics it is important that they also understand linear functions and how to graph them on a Cartesian plane. Then students can understand how to use basic mathematics in their own life and how it can benefit them (cited in Knuth, 2000).

Due to the adoption of the Common Core State Standards, several mathematical topics (such as the methods of solving systems of equations) have been revamped in 2013. The following are 9th grade standards that focus on solving linear equations:

Reasoning with Equations and Inequalities

Solve systems of equations [Linear-linear and linear-quadratic]:

a. Prove that, given a system of two equations with two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.

b. Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations with two variables (California Department of Education, 2013, p.66).

When analyzing the Common Core state standards, students start to learn how to solve real world problems that introduce linear functions as early as the 7th
grade. In the 8th grade, students start to graph linear functions and analyze how the equation affects the graph. High school students are able to graph linear functions and analyze them. Students must also learn to graph several linear functions on the same graph and analyze the relationship between them. This includes solving systems of linear equations algebraically and graphically (California Department of Education, 2013; Kirvan, Rakes & Zamora, 2015).

In a study with 366 secondary school math teachers they were asked several questions on how teaching has changed for them with the introduction of the Common Core state standards. The survey showed 56.3% of them were using electronic/digital supplemental material (Roth Mcduffie, Drake, Choppin, Davis, Magaña, & Carson, 2017).

Solving Systems of Linear Equations

Several researchers such as Huntley, Marcus, Kahan and Miller (2007) have discussed that students have a fundamental lack in understanding when it comes to manipulating variables. Students forget that when solving a system of equations whatever you do to one side of the equation you must do to the other side. An example of this would be subtracting 3 from both sides of 5x+3=4x-7 to get 5x=4x-10 (Huntley, Marcus, Kahan & Miller, 2007).

When solving systems of linear equations it is important to understand the point slope formula y=mx+b. Students are used to solving equations with only one variable “x”, but for systems of equations they must solve for “y” as well. In addition, students must understand the parameters “m” and “b”, which are the slope and y-intercept respectfully. Understanding how the variables and
parameters work together will help students create linear functions from word problems (Pierce, Stacey, & Bardini, 2010). Knowing how to solve for variables is important, but students need the proper language skills to explain what is happening with the slope and the y-intercept. Understanding how these parameters affect the graph will allow students to create linear functions from given information (DeJarnette, Hord, & Marita, 2016).

When Fonger, Davis and Rohwer (2018) were looking into solving systems of equations they specified two ways to solve. They wanted to find correlations between students using a computer algebraic system and just paper and pencil. A study was conducted in a public school in the midwest with 31 ninth grade students. Students were given problems with the setup $ax+b=cx+d$ and were asked to solve them using a computer algebraic system and paper and pencil. When students used the computer algebraic system (which was just graphing software) they had to split the equation $ax+b=cx+d$ into two linear equations $f(x)=ax+b$ and $g(x)=cx+d$. The intersection of the two lines gave the $x$ and $y$ values. When students used the paper and pencil method they had to solve for just $x$ in the form $ax+b=cx+d$. There were two types of problems that proved difficult for the students: 1) when there was no solution because the lines were parallel and 2) when there were infinitely many solutions because the lines were on top of each other. When parallel, students noticed the lines had the same slope but different $y$-intercepts. An example of this would be $4x+3=4x+7$. On the other hand an example of a system of equations with an innumerable amount of solutions would be $4x+3=4x+3$. 
Switching back between the computer algebraic system and the paper pencil method was useful for the students who were average or above. For the students who are average or above it was easy for them to check their own work and talk to the teacher or another student about what they learned. They had less difficulty spotting an equation that had no solution or infinitely many solutions by graphing the linear equations. Students who had lower scores were less motivated to work on the problems. It was hypothesized that there needed to be a story aspect included or at least more verbal checking for student comprehension (Fonger, Davis, & Rohwer, 2018).

Best Practices For Teaching Mathematics

Research shows that teachers tend to teach in the same way that they learned during their years as students, such as teaching out of the textbook or giving a lecture. Even though teaching from the textbook and using worksheets have been used for years, teachers are currently encouraged to get out of their comfort zone and use new instructional strategies such as digital technology and manipulatives in the classroom. Repeating the same type of lesson plan every day gets too repetitive for the students, causing the teacher to lose their attention (White-Clark, DiCarlo, & Gilchriest, 2008).

Motivation is a very important part of student learning. Students need to be engaged in a classroom activity where they can ask questions and be given the chance to show what they have learned. If a student is not engaged in a classroom activity, they will not learn (Kim, Park, Cozart & Lee, 2015). Furthermore, motivation in the STEM subjects drops significantly for secondary
students (Kiemer, Groschner, Pehmer & Seidel, 2015). Kim, Park, Cozart, and Lee (2015) examined the motivation of 100 students enrolled in an online self-paced mathematics course for a semester. They looked at how motivation can turn into engagement, or how a student can have self-efficacy.

Scaffolding plays an important role in how mathematics is taught in a classroom. When scaffolding, it is important to understand the target audience. When working with an individual student, it is important to engage him/her in a constant conversation, asking initial and follow-up questions to gauge comprehension. The same is true when working with a group. In addition, the teacher and students may read the questions several times, checking for understanding. When reading a question, students must find out what they already know and what they need to solve for. During the conversation it is important to use academic language and consistently check for understanding (Moschkovich, 2015).

An alternative method is learner control scaffolding, which uses technology to give the students open-ended questions. In these types of lessons students are given questions, and instead of the teacher giving the students the answer, the teacher gives them resources to find the answer. When tested on a group of students, 75% found this type of learner scaffolding helpful. When students were given a question and the resources to find the answer they are learn that the question can be solved using several different methods. This strategy encourages students to work together and teach each other to solve problems. When giving students questions to solve, it is important to give them a
wide variety so they can use various methods to solve them. Giving students questions to solve is important because they are able to practice what they have learned.

The interaction between scaffolding and dialogue teaching occurs when teacher and student interact through dialogue and the student is able to inquire about the method s/he did not understand. With proper scaffolding, a student will have the ability to work on harder problems and use dialogue in the classroom expressing questions that are more complicated than what is being taught. Helpful scaffolding practices include: 1) pausing before responding to a student, allowing them time to think, 2) using manipulatives in class for conversation starters and 3) looking over student work to see where common misconceptions are occurring (Bakker, Smit, & Wegerif, 2015).

In a study conducted by Denham about digital games being used to teach mathematics. Dragon Box algebra an online paid service with several math games was being used in these classes. When using math games in the classroom it was found that it benefited students more when the game was given to them before the lesson rather during or after the main lesson. This was due to students reading the directions more carefully so that they were able to advance to the next level. It should be noted that not all educational games are beneficial to a student learning (Denham, 2018).
Role of Technology in Teaching Mathematics

Computer assisted instruction has been debated for years, investigating if computers help or interfere with student learning (Witte, Haelermans, & Rogge, 2014). In a survey conducted by the Census Bureau in 2015, it was found that 78% of people have a laptop or desktop at home, 75% have a smartphone, and 77% have internet access (Ryan, & Lewis, 2017) Lynch and Kim (2017) explain how students with access to technology are more likely to work on math at home (Lynch & Kim, 2017).

For an eLearning module to be successful students must get a sense of accomplishment for the tasks they complete. In addition, the module must have a user friendly interface. When a student works with technology and uses it as supplementary material in the classroom they are able to move at their own pace. On the other hand, students who get lost or frustrated need additional help from their teacher so as not to stop using the technology nor get off task in class. The use of educational software as supplementary material in a mathematics classroom revealed that it increased student performance from the 50th to the 55th percentile (Witte, Haelermans, & Rogge, 2014).

A study by the University of Cincinnati discussed the topic of Khan Academy in a classroom and how students used it during class. Khan Academy is an online math website in which students are able to watch videos and work on computer generated problems based on those videos. Khan Academy was used in four different school districts and focused on five student-types with different socioeconomic status and English language fluency. What was examined in each
of the classrooms was 1) the amount of time spent on Khan Academy and 2) how it benefited each student. Students were encouraged to watch the videos at home for homework, but the videos were again played in class for the students who were not able to watch the videos at home. Even if students did have access to the internet, and were able to watch the video at home, they were able to complete the questions while the teacher went over the video in class. Although Khan expected Khan Academy to be used for one-fifth of classroom time, teachers used it for longer periods of time because it allowed students to complete work at their own pace (Cargile & Harkness, 2015).

A study conducted by Schmidt and Ralph (2016) found that 99% of teachers that incorporate a flipped classroom will continue to use the flipped classroom method for future classes. A flipped classroom is when students watch the lecture at home, try to work on problems by themselves and go to class to get help on what they could not understand. The study found that 46% of teachers flipped their math classrooms, which was the second most common subject to use this method. For several of these classrooms, Khan Academy was used as one of the main resources. Khan Academy allows teachers to compile data on students in the classroom. This in turn, allowed, the teacher to see how much time students spent watching videos, or how many exercises a student has gone through. Teachers were able to send students home to get personalized help on problems they were having difficulty with by using videos, practice problems and quizzes (Schmid & Ralph, 2016).
This was further explored by Kirvan, Rakes, and Zamora (2015) to see if a flipped classroom would benefit 54 middle school students learning systems of linear equations. The students were split up into two groups—the control group which followed traditional classroom instruction and the flipped classroom model. In the flipped classroom model the teacher used videos from Khan Academy and put them on Edmodo so that students could access them. Students were also assigned guided notes and up to six problems that they must solve based on the video they watched. Initially, the videos were reviewed in class so that the teacher could explain the content to students. But this gradually changed so that the students had to watch the videos at home. This improved student motivation and participation in-class since students. Overall both groups of students showed similar growth, but the flipped classroom group displayed stronger understanding of systems of equations (Kirvan, Rakes & Zamora, 2015).

Greenhow (2015) discusses the importance of computer aided assistance. If a student is given a problem and asked to solve it but makes one mistake, it is hard for a computer to localize the step in which the mistake was made. If a problem is broken up into several steps, and each step is tested to see if it is correct, a computer is able to give stronger feedback to assist the student. Another strategy would be to put in a random element where not all students would be working on the exact same problem, but similar problems. For example students could solve problems that require similar steps but just use different numbers. Another strategy would be using multiple choice questions with one of
the options as “none of the above”, which encourages student to checking their answers (Greenhow, 2015).

When teachers use interactive technology in the classroom there needs to be a partnership between the teacher and the technology. In a two year study done by Cayton, Hollebrands, Okumuş and Boehm (2017), three high school teachers created a best practices guide to help users have a better understanding of how to use Geometer's Sketchpad—a graphing software in which one can graph functions on the Cartesian plane. This study identified pivotal teaching moments. Pivotal teaching moments are when a teacher interrupts the class to ask students questions to confirm a successful transfer of knowledge. The conversations between the teacher and the students were analyzed to determine the sources of confusion and misunderstanding.

These researchers suggest that using interactive technology allows learners to ask questions that promote higher level thinking and understanding about the topic they are learning. For example, the most common questions asked were procedural and factual, which showed little to no improvement in the students understanding of mathematics. Students were more focused on asking what they should do next to solve a problem rather than why it is the next step. A change was noticed when one of the teachers started off with a procedure or fact then asked a probing question. For example, in one of the teacher’s classes pre-constructed sketches were created on the computers and given to groups of students to discuss and solve. When students were done the teacher asked probing questions about what they went over. A strategy the teachers
implemented for the classroom was to have locations where students could go and catch up on, get help with or even get ahead in class work (Cayton, Hollebrands, Okumuş, & Boehm, 2017).

A large study was conducted in an economically disadvantaged school district at middle and high schools where students were most likely to have learning loss over the summer. Two main groups of students used math packets over the summer, while a third group used technology. The technology tools were personal laptops, TenMarks, and Khan Academy. TenMarks and Khan Academy are online services in which teachers are able to assign videos and practice problems. Students in the group with laptops were 12% more likely to be working on math at home. Also, the students who reported using Khan Academy were significantly more prepared for algebra (Lynch & Kim, 2017).

**Summary**

Solving systems of linear equations is an important skill in math. It proves useful when creating shapes on the Cartesian plane in geometry or graphing the derivative of a quadratic function. The Common Core State Standards have made it easy for teachers to access online materials to use in the classroom so that students can be successful in the future.

Not understanding systems of linear equations will be detrimental to understanding mathematics in future classes. Linear equations are the foundation of algebra in which they explore a function with two variables “x” and “y” along with the parameters “m” for slope and “b” for the y-intercept.
There are many best practices that have been used for teaching math. Teachers are encouraged to get out of their comfort zone and try new ways to approach teaching the same material. Students need engaging material that will keep their attention during class time. Math is a subject that builds upon itself. If a student has not had proper scaffolding of the material they will not be able to grasp any new content.

Teaching mathematics is constantly changing due to the ever improving technological applications that are created every year. More people own a technological device to be able to access these eLearning tutorials whether it is Khan Academy or any other interactive technology. Learning online is easier than ever. It does not matter what language someone speaks or if they have a disability. The language on an eLearning module can be switched and web pages can be zoomed in or the text read to you.
CHAPTER THREE

METHODOLOGY

The purpose of this project was to create a web-based, eLearning module to teach 9th grade high school students how to solve systems of linear equations algebraically and graphically. This lesson was intended as a supplementary material for students to review and practice their skills on systems of linear equations.

The ADDIE model was used for the development of this project. ADDIE is an acronym for Analysis, Design, Development, Implementation, and Evaluation. Each phase of the ADDIE model builds on the past steps to help create material that can be used to successfully teach needed skills (Molenda, 2015)(see Figure 3.1).

![ADDIE Model Diagram](image)

Figure 3.1 The ADDIE Model (Braunschweig, 2014, ¶1).
Content Development

Content development covers the first two phases of ADDIE Model: Analysis Phase and Design Phase.

Analysis Phase

During the Analysis phase information is gathered for developing relative material that can help learners develop important skills (Cheung, 2016). Information was collected through an informal needs assessment. Conversations with several high school math teachers revealed that a self-guided module to review the different ways to solve system of linear equations could be helpful to students who are struggling with the process of solving systems of linear equations. Teachers noted that it would be useful if students could access this material online at their own convenience. Teachers noted that students are more likely to graph the lines and see where they intersect using technology.

Audience Analysis: This project focused on the Common Core State Standards and on systems of linear equations. This project was limited to ninth grade math students. The students in ninth grade are around 13 to 14 years of age. During class and tutoring sessions it was noted that systems of linear equations was a topic of difficulty for students. Students background with this topic goes back to the 7th and 8th grade when they learn about linear equations. It was observed that students did not know every way to solve systems of linear equations or that they were using a method that made it harder to solve the problem.
Objective Analysis: The following is the objective of this project:

- Students will be able to apply four different methods to solve systems of linear equations.

Technology Analysis: All students currently possess a chromebook that was provided by the school. A majority of students have a personal cell phone, as well. They are proficient with chromebooks since they have been using them since middle school. Students use Google classroom, Desmos, and Khan Academy in the classroom. The web browser that students are using is Google Chrome. Chromebooks were given to each student so that they can follow along with Google Classroom, Khan Academy and Desmos. The students used both Chromebooks and smartphones to access school material.

Extant-Data Analysis: In meetings with the teachers and by conducting observations in the classrooms, it was observed that students were taught how to learn systems of linear equations in many different ways. Students used workbooks that follow the Common Core State Standards and use technology to further investigate the material that they are learning.

Design Phase

After the completion of the analysis phase the next step is the design phase. During the design phase, the instructional designer decides in what format the material will be delivered to the learners (Cheung, 2016).
Common Core State Standards

After reviewing the Common Core State Standards and current lesson plans used by teachers the content of the project was broken down into the following:

- Review of the Common Core State Standards related to solving systems of linear equations.
- Solving systems of linear equations algebraically: Given two linear functions \( y=mx+b \) set both functions equal to each other to solve for “x”. Then plug in the “x” to one of the original functions to solve for “y”.
- Solving systems of linear equations graphically: Graph both of the lines and see where they both intersect. This does not work the best when the point slope formulas have decimals or fractions.
- Solving systems of linear equations by substitution: Given two functions \( y=mx+b \) and \( x=y+b \). Substitute \( x=y+b \) for the other equation’s x-value and solve for “y”. Then plug “y” back into one of the original functions to solve for “x”.
- Solving systems of linear equations by elimination: Remove variables until there is only one left. This can be done by multiplying a function so that variables can cancel out.

Interactivity Embedded in the Project

The project had four sections with each containing a method to solve systems of linear equations using videos to explain the process. Interactivity was
built into this project through exercises for students to do with every method as follows:

- **Videos:** Students were able to watch videos on each of the methods of solving systems of linear equations in four different ways.
- **Interactive Questions:** Several types of questions were used to ask in the form of multiple choice, drag and drop, fill in the blank and more.
- **Students were able to interact with the activities embedded on each section of the lesson.**

**Program Development**

Program development covers the Development Phase of the ADDIE model.

**Development Phase**

Once the design phase is completed, the instructional designer moves on to the development phase. The development phase covers the production, organization and presentation of material (Cheung, 2016).

The hardware used to create this project was an HP laptop using Windows 10 operating system. Storyline 3 from Articulate was the software used to create the eModule (see Figure 3.3). The graphs were created using Desmos. Screenshots of those graphs were produced using the snipping tool. The screenshots were saved as JPEG format. The snipping tool allowed the instructional designer to capture portions of the screen. The graphics for this project were all JPEG image files.
Algebraically
Given two linear functions \(y = mx + b\), set both functions equal to each other to solve for \(x\). Then plug in the \(x\) value of one of the original functions to solve for \(y\).

Graphically
Graph both of the lines and see where they both intersect. This does not work the best when using point slope formulas that have decimals or fractions.

Substitution
Given two functions \(y = mx + b\) and \(x = i + p\), substitute \(x = i + p\) for the other equation. Solve \(x\) for \(y\), then plug the \(x\) value into one of the original functions to solve for \(y\).

Elimination
Remove variables until there is only one left. This can be done by multiplying one function so that variables can cancel out.

Figure 3.2 Articulate Storyline 3 Interface.

Kuta was used to create some of the math problems. Kuta is a software that creates math questions quickly to be used on worksheets, tests, and any other math based assignments. Some of the equations in this project were created by the instructional designer so that they would fall into the proper parameters and thus be easily analyzed on a graph. All graphs were created using Desmos and Kuta. A screenshot of the graphs was taken and placed in the project. The slides were connected to each other using buttons to help the user navigate between slides. Adjustments on the timeline of Storyline 3 were made to prevent students from skipping to the next scene automatically.

Videos were created using Articulate Replay for each section of the project. Paint, a digital paint board, provided a whiteboard during the recording of the videos to draw and show the steps to solve each equation. The videos were exported as MP4 video files and embedded into the project to guide students in
solving equation problems. The audio narrations of the video clips were created using Logitech h390 headphones with a mic with Articulate Replay.

Before the recording of the video, the explanation was written down on Paint and used as a script for the narrations. The screen recordings were cut and pasted together from several short recordings to create a longer video. After the videos and the storyline project were created, the project was uploaded to Cal Poly Pomona Server and a URL was generated.

**Field-Testing Procedure**

The field testing procedure covers the last two phases of ADDIE Model: Implementation phase and Evaluation phase.

**Implementation Phase**

The fourth phase of ADDIE is the implementation phase. During this phase, the instructional designer publishes and uploads the material for the learners (Cheung, 2016).

Specific steps had to be taken before field testing could occur. For safety and security reasons, public schools may block certain sites so the project had to go through a thorough testing and troubleshooting to make sure that the links were active and the websites used within the project could be accessed by the students. Preliminary testing and troubleshooting was done on a school computer identical to the students’ computers. To make sure that the project was accessible, it was loaded and tested on both Mac and PC computers. The project was also tested on Google Chrome, Firefox and Safari. The project was
accessible on computers using a mouse, computers using touch screen, and on laptops and smart phones.

**Evaluation Phase**

The last phase of the ADDIE model is the evaluation phase. This phase examines how effective the lesson was and gives feedback to the instructional designer (Cheung, 2016). The evaluation phase includes summative evaluation and formative evaluation. Formative evaluation is conducted during the development of the material. Summative evaluation occurs at the end of the course to determine how effective the material was learned. The feedback from the evaluation phase allows the instructional designer to determine what information was beneficial to the learner and what needs to be improved (Cheung, 2016).

To field test this project, the Kirkpatrick’s 4-Level Training Model was used. The Kirkpatrick’s Model takes into account all style of training, to determine aptitude based on four levels: Reaction, Learning, Behavior, and Results (Kurt, 2016).

- Level 1-Reaction: Analyzes the participant’s satisfaction with the training.
- Level 2-Learning: Analyzes if the learner has acquired new knowledge based on the training content.
- Level 3-Behavior: Analyzes the participant’s behavior to find out if transfer of knowledge has happened.
- Level 4-Results: Analyzes the outcome as a result of the training.
The first level of the Kirkpatrick’s model was used to field test this project. It is important to understand that there is limited time in the classroom so a participant satisfaction regarding the training will vary based on their background knowledge of the topic.

The following steps were taken to field test this project:

- Receiving approval from the school’s principal (see Appendix A).
- Receiving approval from Institutional Review Board of California State Polytechnic University, Pomona (see Appendix B).
- Delivering a pitch for the project to students in math 1 classes about the project (see Appendix C).
- Handing out Consent forms to students to take home to parents and/or guardians to review and sign if interested (see Appendix D).
- Handing out Assent forms to students to take home to parents and/or guardians to review sign if interested to participate in the study (see Appendix E).
- Pick up signed Consent and Assent forms from students.
- Students who have permission to participate by turning in the forms will be given access to the project. The project website will be given to them on a separate sheet of paper so that only those who have permission could go through the project.
- Students without consent forms to participate will be working on Khan Academy in the classroom.
At the end of the project students will have a link they that will send them to an anonymous survey on Survey Monkey (see Appendix F).
CHAPTER FOUR
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Teachers have started integrating technology to assist them with teaching mathematical concepts every day. The use of technology is extremely helpful when graphing simple linear functions (Lynch & Kim, 2017; Witte, Haelermans, & Rogge, 2014). The common core state standards for math rely on technology even more than ever before when it comes to teaching linear functions (Pierce, Stacey, & Bardini, 2010). Systems of linear equations are often confusing, but with the help of technology, it can help become more clear and less confusing (Cai, Nie, & Moyer, 2010).

Multiple options are available to solve mathematical problems. Systems of linear equations are solved using four main strategies taught in the classroom: 1) graph each equation and see where the lines intersect on a graph, 2) set both equations equal to each other, 3) substitute one equation into the other and 4) multiply the equation so that a coefficient can be canceled out. It is important that students understand how to use each method (Fonger, Davis, & Rohwer, 2018).

Teachers are starting to use math related technologies in the classroom even though it is dramatically different from the way that they were taught at school (White-Clark, DiCarlo, & Gilchriest, 2008). Scaffolding mathematical material is extremely important due to the fact that math builds upon itself. During this process students need gradual self practice for a chance to make sure that they understand the process (Moschkovich, 2015; Edson, 2017). Research has
shown that having access to technology in the classroom and at home
significantly improves students' academic performance (Lynch & Kim, 2017).

To solve systems of linear equations, students must use two linear
equations in the form of $y=mx+b$, both containing two variables (Cai, Nie, &
Moyer, 2010). Students struggle when they are asked to solve a system of
equation and manipulate the equation at the same time. Degrees of confusion
will vary based upon the students prior knowledge to the concepts (Huntley,
Marcus, Kahan, & Miller, 2007; Fonger, Davis, & Rohwer, 2018). Students have
the ability to describe what they are doing talking about the math terminology and
how it applies to the problems that they are solving (Adu-Gyamfi, Bossé, &
Chandler, 2015).

From the previous information, the Instructional Designer created an
interactive web-based, eLearning module to teach 9th grade high school
students how to solve systems of linear equations algebraically and graphically.
The ADDIE model was used for the development of this project. ADDIE is an
acronym for Analysis, Design, Development, Implementation, and Evaluation.
The Instructional Designer created videos, images and other multimedia options
components.

There are four main sections in this project. Each one covers a different
way to solve systems of linear equations. Each section has videos that go over
each method of solving systems of linear equations. The videos were created
using Articulate Replay which is a screenshot recording software. Screen
capturing Microsoft Paint allowed for all the problem solving to be visually
explained in the videos. Students were able to interact with the slides and learn about each of the steps. There are several spots in the project where students were able to pause and review what they have just learned to determine if they understood the section. The questions were created using templates provided in Storyline 3.

To field test this project, Kirkpatrick 4-Level Training Module was used. The Kirkpatrick Model takes into account four levels of training: Reaction, Learning, Behavior, and Results. This project was field tested based on level one of the Kirkpatrik’s model.

After permission was given from the principal (see Appendix A), and the IRB approved of the project (see Appendix B) the pitch for the project was presented to the students so they could better understand what they were going to learn during the eModule (see Appendix C). Before students were given the digital lesson plan, a permission slip was sent home to be signed by their parent/guardian so that they could participate (see Appendix D). Along with getting permission from the parents/guardians, an assent form was given to the students so that they could also decide if they want to participate (see Appendix E). Students with signed consent and assent forms were given access to the eLearning Module. Students without signed consent and assent forms were given another equivalent assignment by their teacher. Consent and assent forms were distributed in English on one side and Spanish on the other (see Appendix D). The forms were distributed by the Instructional Designer during the beginning of class and students were given two days to return them if they wished to
participate. After signed consent and assent forms were collected by the Instructional Designer, the access to the eModule was given to only those students who turned in the completed forms. Once the students completed the project they responded to a ten-question survey (see Appendix F).

The field testing took place in a classroom in a California school district in a 9th grade math classroom. Students were given the URL address of the project. Instructions were given at the beginning of class. Students were given one period to complete the eModule. While students were working on the lesson and needed help, they could raise their hand and ask for assistance. Field testing in the classroom took no more than one class period.

At the end of the project, students were given a link to an online anonymous survey. In the survey, students were asked to answer ten questions based on the students' overall opinion of the website navigation, coverage of material, experience, organization, pace, understanding, learning style and changes or additions to the project students would like to see.

Twenty-eight ninth-grade students were invited to voluntarily participate in a field testing. Fourteen of those students completed the project and answered the survey questions. The aggregated responses of the participants are presented in the following section.
Conclusions

In the last screen of the project, there was a link to an anonymous ten-question survey on Surveymonkey.com for the students to provide feedback on their experience with the project (see Appendix F)

**Question 1: Was the website easy to navigate?**

The “Navigation” question was to measure the overall ability for the user to explore the project. Five out of fourteen (38.46%) participants responded “Extremely easy”. Five out of fourteen (38.46%) participants responded “Very easy”. Three out of fourteen (23.08%) participants responded “Somewhat easy”. Zero out of fourteen (0%) participants responded “Not so easy”. Zero out of fourteen (0%) participants responded “Not at all easy”. One participant skipped this question (see Figure 4.1).

![Was the website easy to navigate?](image)

*Figure 4.1 Easy to Navigate*
Question 2: Would you like to have more lessons like this?

The “Lesson Preference” question was to determine if the user enjoyed this way of learning and would want to use this method to learn this way more often. Fourteen out of fourteen (100%) participants responded “yes”. Zero out of fourteen (0%) participants responded “no” (see Figure 4.2).

![Preference for eModule](image)

Figure 4.2 Preference for eModule

Question 3: Did the training cover ...

The “Training Coverage” question was to ask the user how they think the training covered the content. Zero out of fourteen (0%) participants responded “Too much information”. Zero out of fourteen (0%) participants responded “Too little information”. Fourteen out of fourteen (100%) participants responded “Right amount of information” (see Figure 4.3).
Figure 4.3 Training Coverage

Question 4: Did you experience any of the following while going through the program? (Please select all that apply.)

The “Experience going through the program” question was to ask the users if they had any issues with the project. One out of fourteen (12.5%) participants responded “Website did not display properly on desktop”. Zero out of fourteen (0%) participants responded “Too many pop-ups”. Zero out of fourteen (0%) participants responded “Pictures, videos or buttons did not work or showed up”. One out of fourteen (12.5%) participants responded “Pages loaded too slowly”. One out of fourteen (12.5%) participants responded “Navigating the program was confusing”. Five out of fourteen (62.5%) participants responded “Other (please specify)”. Six participants skipped this question (see Figure 4.4).
Did you experience any of the following while going through the program?
(Please select all that apply.)

<table>
<thead>
<tr>
<th>Experience</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
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<td>12.50%</td>
<td></td>
</tr>
<tr>
<td>Too many pop-ups</td>
<td>12.50%</td>
<td></td>
</tr>
<tr>
<td>Pictures, videos or buttons did not work...</td>
<td>12.50%</td>
<td></td>
</tr>
<tr>
<td>Pages loaded too slowly</td>
<td>12.50%</td>
<td></td>
</tr>
<tr>
<td>Navigating the program was confusing</td>
<td>62.50%</td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td>62.50%</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4.4 Experience going through the program**

In the fourth question there was another response to determine if other issues raised during the testing of this eModule (see Table 4.1)

<table>
<thead>
<tr>
<th>Answers to Question 4</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
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<tbody>
<tr>
<td>No issues</td>
<td>4 answers out of 14</td>
<td>28.57%</td>
</tr>
<tr>
<td>Could not click on an object</td>
<td>1 answer out of 14</td>
<td>7.14%</td>
</tr>
<tr>
<td>No response</td>
<td>9 answers out of 14</td>
<td>64.29%</td>
</tr>
</tbody>
</table>

**Table 4.1 Other Experiences**

**Question 5: How organized was the course?**

The “Organization” question was to check with the user to see how organized material in the project was presented. Three out of fourteen (21.43%) participants responded “Extremely well-organized”. Six out of fourteen (42.86%) participants responded “Very well-organized”. Five out of fourteen (35.71%) participants responded “Somewhat organized”. Zero out of fourteen (0%)
participants responded “Not so well-organized”. Zero out of fourteen (0%) participants responded “Not at all organized” (see Figure 4.5).

**Figure 4.5 Organization**

**Question 6: Was the pace of the material presented in the project Too Fast, About Right, or Too Slow?**

The “Pace of the Project” question was to determine is the speed at which the material was presented was at a good pace for the user. Zero out of fourteen (0%) participants responded “Too fast”. Fourteen out of fourteen (100%) participants responded “About right”. Zero out of fourteen (0%) participants responded “Too slow” (see Figure 4.6).
Figure 4.6 Pace of the Project

Question 7: Did the quizzes help you understand what each lesson was trying to teach you?

The “Quizzes” question was to determine if the user was able to answer the questions asked in the project. Thirteen out of fourteen (92.86%) participants responded “yes”. One out of fourteen (7.14%) participants responded “no” (see Figure 4.7).

Figure 4.7 Helpful Quizzes
Question 8: Would you prefer to learn from a project like this instead of learning from a textbook?

The “Project or Textbook” question was to check with the users to see if they would choose this learning method over a traditional textbook method of learning. Five out of fourteen (35.71%) participants responded “Strongly agree”. Seven out of fourteen (50%) participants responded “Agree”. Two out of fourteen (14.29%) participants responded “Neither agree nor disagree”. Zero out of fourteen (0%) participants responded “Disagree”. Zero out of fourteen (0%) participants responded “Strongly disagree” (see Figure 4.8).

Figure 4.8 Preference for eModule or Textbook

Question 9: Would you prefer to learn from a project like this instead of learning from a lecture?

The “Project or Lecture” question was to check with the users to see if they would choose this learning method over a traditional lecture method of learning. One out of fourteen (7.14%) participants responded “Strongly agree”. Seven out of fourteen (50%) participants responded “Agree”. Five out of fourteen
(35.71%) participants responded “Neither agree nor disagree”. One out of fourteen (7.14%) participants responded “Disagree”. Zero out of fourteen (0%) participants responded “Strongly disagree” (see Figure 4.9).

Figure 4.9 Preference for eModule or Lecture

Question 10: Is there anything you would like to be added or changed in this project?

This resulted in eight out of fourteen responses. The input that participants found very few issues with the project is a positive result. One responded that did stand out was that a participant thought a calculator in the project would have been useful. Another participant wanted to see things changed to match their personal preferences (see Table 4.2).
<table>
<thead>
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<th>Answers to Question</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
</tr>
<tr>
<td>No issues</td>
<td>6 answers out of 14</td>
<td>42.86%</td>
</tr>
<tr>
<td>Could not click on an object</td>
<td>2 answer out of 14</td>
<td>14.29%</td>
</tr>
<tr>
<td>No response</td>
<td>6 answers out of 14</td>
<td>42.86%</td>
</tr>
</tbody>
</table>

Table 4.2 Response Questions

**Recommendations**

By analyzing the data that was provided by the surveys the perception of the project was overall positive the project Solving Systems of linear equations: an eLearning module for ninth graders. The majority of the participants found that the project was well organized and covered just the right amount of material in the time allotted to complete this project. Students preferred to learn from a project like this rather than a textbook but when it came to a traditional lecture students still preferred the way material was presented in this project but some still wanted to a traditional lecture. Participants did find issues with the project that some buttons that did not work and they wanted additional things changed or added to the structure of the project.

**Suggestions for improving this Project**

The project had an overall positive response from the participants. The suggestions from the participants will help in the effort to improve this project. Having an easy to access calculator or graphing software that the participants could use to during their use of the project. Another survey could also be taken
about the design of the project to help with the visualization and different aspects of material in the project.

**Recommendations for Future Research**

This project was created as a need for students to better understand how to solve systems of linear equations. Students struggle with solving systems of linear equations since they now need to understand how two equations work and how the effect each other on the graph and algebraically. There are many units in math where a project like this can be a useful tool to learn or review information. Data gathered from this study can help future researchers create eLearning modules to teach a variety of topics to learners across the world.
REFERENCES


doi:10.1016/j.jmathb.2007.05.005


Appendix A
Principals Approval

To whom it may concern,

I have reviewed Joshua Keagy project and he has my approval to test his project, SOLVING SYSTEMS OF LINEAR EQUATIONS: AN eMODULE, in math 1 classes at [redacted].

Should you have any questions or concerns feel free to respond to this email or call me.

Best Regards,
Appendix B

Institutional Review Board Approval

Ex: IRB-18-223 - Initial: CPP Expedited Approval

irb-office@cpp.edu
Wed 12/4/2019 11:53 AM
To:

• Joshua A. Keagy <jakeagy@cpp.edu>;
• Shahnaz Lotfipour <slotfipour@cpp.edu>

Memorandum
California State Polytechnic University, Pomona
Institutional Review Board -- Office of Research Compliance

Federalwide Assurance 00001759 -- IRB principles: respect for persons, beneficence, and justice

Date: December 4, 2019
PI Name: Joshua Keagy; Department/College: Educational Multimedia
Co-PI(s): Shahnaz Lotfipour
IRB Protocol Number: IRB-18-223
Protocol Title: Solving systems of linear equations to 9th graders: An eLearning Module
Protocol Submission Type: Initial; Review Board Type: by CPP IRB members
Review Type: Expedited
Decision: Approved

Dear Investigator(s),

The protocol as described above has been reviewed by the Cal Poly Pomona Institutional Review Board (IRB) by the expedited review method. It was found to be in compliance with applicable federal and state regulations and Cal Poly Pomona policies regarding the protection of human subjects used in research. Thus, the Cal Poly Pomona IRB grants you approval to conduct the research. On its behalf, I thank you for your adherence to established policies meant to ensure the safety and privacy of your study participants. You may wish to keep a copy of this memo with you while conducting your research project.

You may initiate the project as of December 3, 2019, and it must be completed by December 2, 2020. Please remember to submit a request to the IRB at least six (6) weeks before this end date to ensure continuous human subjects’ protection and IRB approval. The Cayuse system will remind you, however the responsibility lies with the
study investigators.

It would be appreciated that you advise the IRB upon the completion of your project involving the interaction with human subjects. Please use the "Closure or termination of the protocol" form in the Cayuse system.

Approval is conditional upon your willingness to carry out your responsibilities as the principal investigator under University policy. Your research project must be conducted according to the methods described in the final approved protocol. Should there be any changes to your research plan as described, please advise the IRB, because you may be required to submit an amendment (with re-certification). Additionally, should you as the investigator or any of your subjects experience any "problems which involve an undescribed element of risk" (adverse events in regulatory terms), please immediately inform the IRB of the circumstances. There are forms for both in the Cayuse system.

These are additional notes, if any, from the Board: Corrections to the parent Informed Consent Form.

The committee wishes you success in your future research endeavors. If you need further assistance, you are encouraged to contact the IRB.

Sincerely,

Heather Taylor Wizikowski

Heather Taylor Wizikowski, Ph.D.
Chair, Institutional Review Board
Associate Professor, Education
College of Education and Integrative Studies

This message has been automatically generated by the Cayuse system installed at Cal Poly Pomona. Please contact the IRB office (irb@cpp.edu or 909.869.4215 or .3713) if you have questions or you believe you have received this message in error. Thanks for your compliance with the regulations while conducting human subjects research. [2/13]
Appendix C

Student Recruitment Script

Oral Script for 9th grade student recruitment for this study

Good Day, Everybody! I’m currently a student at Cal Poly Pomona, working on my Master’s degree. One of the last things I need to do before I can graduate is to do a research study. I am talking to you today to see if you are interested to check out a math eLesson that I have created. My goal was to create a fun and interactive website which allowed students to work at their own pace. I created all of the videos tutorials and all of the other interactive elements in this project.

This eLesson is on the topic of systems of linear equations, which is one of the Common Core State Standards that you are expected to learn this year. Specifically this eLesson is about the four main ways to solve systems of equations. You’ll be using your chromebook and a website for one class period during math class to go over my project. At the end of the class you’ll complete an anonymous online survey telling me what you thought about this project.

If this eLesson sounds interesting to you, I will give you a Consent and Assent form. Make sure that both you and your parent or guardian review them and if your parents are interested sign and date the forms.

Participation is completely voluntary, but only the ones with signed forms can participate. You won’t be punished for not participating, and your grade will not be affected. If you don’t participate in this study, then you will be working on your chromebook on an assignment that created.

If anybody has any questions, please raise your hand.

(Researcher answers any questions from students)

If anybody is interested in, or might be interested in participating in the survey, please make sure to get a permission slip from me. You will need to turn it in by Friday the 6th of December if you want to participate.

Thanks, everybody.
Appendix D

Consent Form

California State Polytechnic University, Pomona
Informed Consent Form for Research Involving Human Subjects

Consent Form

Your Child is being invited to participate in a research study, which the Cal Poly Pomona Institutional Review Board (IRB) has reviewed and approved for conduct by the investigators named here. This form is designed to provide your child - as a human subject/participant - with information about this study. The investigator or his/her representative will describe this study to your child and answer any of their questions. You are entitled to an Experimental Research Subject's Bill of Rights and a copy of this form. If you have any questions about your rights as a subject or participant, complaints about the informed consent process of this research study, or experience an adverse event (something goes wrong), please contact the Research Compliance Office within Cal Poly Pomona's Office of Research at 909.869.4215. More information is available at the IRB website, http://www.cpp.edu/~research/irb/index.shtml

Solving Systems of Linear Equations to 9th graders: An eLearning Module
Primary Investigator: Joshua Keagy  Email: jakeagy@cpp.edu
Faculty Advisor: Dr. Shahnaz Lotfipour Email: slotfipour@cpp.edu
IRB protocol # 18-223

Purpose: My name is Joshua Keagy, and I am currently a graduate student at California State Polytechnic University, Pomona, pursuing a Master's degree in Educational Multimedia. For my Master's project, I have developed an eLearning module on systems of linear equations, which is one of the Common Core State Standards for 9th grade mathematics. This eLesson module is on a website, and will teach your child the basics of solving systems of linear equations by having him/her work through the problems. This website includes pictures and videos that will help make systems of linear more understandable to your child.

Voluntary Status: Your child has met the requirements for enrollment as a volunteer in a research study conducted by the researchers listed above. Your child is now being invited to participate in this study. Before you can make your decision, you will need to know what the study is about, the possible risks and benefits of being in this study, and what your child will have to do in this study. If you have any questions, please ask the researcher for an explanation. If you decide to let your child participate, you will be asked to sign this form. Your child's participation is voluntary. Your child may withdraw at any time without penalty and there will be no loss of any benefits to which your child is entitled.

Procedures: In this study, your child will work individually and will spend one class period to complete this eLearning module using the website to complete its activities. Afterwards, your child will be asked to complete a five minute confidential survey of their opinions about the website. This survey is meant to help inform me of ways to improve this educational website. No student names will be asked on the survey. I will be the only person who will have access to the survey, and the results will be deleted/destroyed once the study is complete and approved by the university.

Commitment and Compensation: Your child total participation in the study will take one class period, which will last approximately 30 minutes. Your child will not receive financial compensation for participation in the study.
**Possible Risks and Benefits:** It is expected that participation in this study will provide your child with no more than minimal risk or discomfort, which means that your child should not experience any more difficulty than what would occur in their normal daily life or in your classroom. However, there is always the chance of an unexpected risk. The foreseeable risks in this study include discomfort by answering questions that your child may have difficulty solving. If your child feels uncomfortable or distressed, please tell the researcher and he/she will ask your child whether they wish to continue. Your child can withdraw from the study at any time without penalty.

**Confidentiality and Consent:** Participation in this study is completely voluntary, and your child will not be penalized in any way if he/she or you decide to not to have him/her participate in the study. If your child decides not to participate on the day of the study, your child may withdraw from the study without any consequences. If your child would like to participate in this study, and you allow your child to participate, please sign this form. If this consent form is not complete and returned, then your child will not participate in this study. If you have any questions please contact me. The study will not collect any personal information. Your child’s identity will be kept strictly anonymous. All results will be presented in groups and in combined format in the researcher’s thesis.

**New Information:** During the course of this study, the investigators may discover information that could be important to your child. They will notify you as soon as possible when such information becomes available.

**Consent:** I consent that my child participate in the study. I understand that my child's participation in this study is entirely voluntary and that my child may refuse to participate or withdraw from the study at any time without penalty. I have received a copy of this consent form for my records.

**Contact Information**
Primary Investigator: Joshua Keagy Email: jakeagy@cpp.edu
Faculty Advisor: Dr. Shahnaz Lotfipour Email: slotfipour@cpp.edu

Turn in this form by Friday the 6th of December if you want your child to participate.

**Parent or Guardian sign**

<table>
<thead>
<tr>
<th>Printed name of parent/guardian</th>
<th>Signature</th>
<th>Date</th>
</tr>
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</table>
Universidad Politécnica del Estado de California, Pomona Formulario de consentimiento informado para investigaciones que involucren sujetos humanos

Formulario de consentimiento

Se invita a su hijo(a) a participar en un estudio de investigación, que la Junta de Revisión Institucional (IRB) de Cal Poly Pomona ha revisado y aprobado para la conducta de los investigadores nombrados aquí. Este formulario está diseñado para proporcionar a su hijo(a), como sujeto / participante humano, información sobre este estudio. El investigador o su representante describirá este estudio a su hijo(a) y responderá cualquiera de sus preguntas. Tiene derecho a una Declaración de derechos de un sujeto de investigación experimental y una copia de este formulario. Si tiene alguna pregunta sobre sus derechos como sujeto o participante, quejas sobre el proceso de consentimiento informado de este estudio de investigación o experimenta un evento adverso (algo sale mal), comuníquese con la Oficina de Cumplimiento de Investigación dentro de la Oficina de Investigación de Cal Poly Pomona: 909.869.4215. Más información está disponible en el sitio web de IRB, http://www.cpp.edu/~research/irb/index.shtml.

Solving Systems of Linear Equations to 9th graders: An eLearning Module
Investigador principal: Joshua Keagy Email: jakeagy@cpp.edu
Consejera de la faculdad: Dr. Shahnaz Lotfipour Email: slotfipour@cpp.edu
IRB protocol # 18-223

Propósito: Mi nombre es Joshua Keagy, y actualmente soy un estudiante graduado en la Universidad Politécnica del Estado de California, Pomona, cursando una maestría en Educación Multimedia. Para el proyecto de mi maestría, he desarrollado un módulo de aprendizaje electrónico sobre sistemas de ecuaciones lineales, que es uno de los Estándares Estatales Básicos Comunes (Common Core State Standards) para las matemáticas de noveno grado. Este módulo eLesson está en un sitio web y le enseñará a su hijo(a) los conceptos básicos para resolver sistemas de ecuaciones lineales al hacer que él / ella resuelva los problemas. Este sitio web incluye imágenes y vídeos que ayudarán a que los sistemas lineales sean más comprensibles para su hijo(a).

Participación voluntaria: Su hijo(a) ha cumplido los requisitos para la inscripción como voluntario en un estudio de investigación realizado por los investigadores mencionados anteriormente. Su hijo(a) ahora está siendo invitado a participar en este estudio. Antes de que pueda tomar su decisión, necesitará saber de qué se trata el estudio, los posibles riesgos y beneficios de participar en este estudio y lo que su hijo(a) tendrá que hacer en este estudio. Si tiene alguna pregunta, solicite una explicación al investigador. Si decide dejar que su hijo(a) participe, se le pedirá que firme este formulario. La participación de su hijo(a) es voluntaria. Su hijo(a) puede retirarse en cualquier momento sin penalización y no se perderán los beneficios a los que tiene derecho.

Procedimientos: En este estudio, su hijo(a) trabajará individualmente y pasará un período de clase para completar este módulo de aprendizaje electrónico utilizando el sitio web para completar sus actividades. Luego, se le pedirá a su hijo(a) que complete una encuesta confidencial de cinco minutos de sus opiniones sobre el sitio web. El objetivo de esta encuesta es ayudarme a informarme sobre formas de mejorar este sitio web educativo. No se preguntarán los nombres de los estudiantes en la encuesta. Seré la única persona que tendrá acceso a la encuesta, y los resultados serán eliminados / destruidos una vez que el estudio esté completo y aprobado por la universidad.
Compromiso y compensación: La participación total de su hijo(a) en el estudio tomará un periodo de clase, que durará aproximadamente 30 minutos. Su hijo(a) no recibirá compensación financiera por participar en el estudio.

Posibles riesgos y beneficios: Se espera que la participación en este estudio proporcione a su hijo(a) un riesgo o incomodidad que no sea más que mínimo, lo que significa que su hijo(a) no debería experimentar más dificultad de la que ocurriría en su vida diaria normal o en su salón de clases. Sin embargo, siempre existe la posibilidad de un riesgo inesperado. Los riesgos previsibles en este estudio incluyen molestias al responder preguntas que su hijo(a) puede tener dificultades para resolver. Si su hijo(a) se siente incómodo o angustiado, dígale al investigador y él / ella le preguntará si desea continuar. Su hijo(a) puede retirarse del estudio en cualquier momento sin penalización.

Confidencialidad y consentimiento: La participación en este estudio es completamente voluntaria, y su hijo(a) no será penalizado de ninguna manera si él / ella o usted decide que no participe en el estudio. Si su hijo(a) decide no participar el día del estudio, su hijo(a) puede retirarse del estudio sin ninguna consecuencia. Si a su hijo(a) le gustaría participar en este estudio y usted le permite participar, firme este formulario. Si este formulario de consentimiento no está completo y no se devuelve, su hijo(a) no participará en este estudio. Si usted tiene alguna pregunta, por favor póngase en contacto conmigo. El estudio no recogerá ninguna información personal. La identidad de su hijo(a) se mantendrá estrictamente anónima. Todos los resultados se presentarán en grupos y en formato combinado en la tesis del investigador.

Nueva información: Durante el curso de este estudio, los investigadores pueden descubrir información que podría ser importante para su hijo(a). Le notificarán lo antes posible cuando dicha información esté disponible.

Consentimiento: Doy mi consentimiento para que mi hijo(a) participe en el estudio. Entiendo que la participación de mi hijo(a) en este estudio es completamente voluntaria y que mi hijo(a) puede negarse a participar o retirarse del estudio en cualquier momento sin penalización. He recibido una copia de este formulario de consentimiento para mis registros.

Información del contacto
Investigador principal: Joshua Keagy Email: jakeagy@cpp.edu
Consejera de la facultad: Dr. Shahnaz Lotfipour Email: slotfipour@cpp.edu

Entregue este formulario antes del viernes 6 de Diciembre si desea que su hijo(a) participe.

Firma del padre o tutor (guardian)

<table>
<thead>
<tr>
<th>Nombre del padre/tutor (en letra de imprenta)</th>
<th>Firma</th>
<th>Fecha</th>
</tr>
</thead>
</table>
Appendix E

Assent Form

Project Title: Solving Systems of Linear Equations to 9th graders: An eLearning Module
IRB#: 18-223
Principal Investigator: Joshua Keagy

Assent Form

My name is Mr. Keagy. I go to school at California State Polytechnic University, Pomona. I am inviting you to participate in a research study about systems of linear equations. This project is full of multimedia components such as videos and interactive assignments to help teach math. Your participation is completely voluntary. This form will clarify my project further, so you can decide whether or not you want to take part in it.

What are you being asked to do?
If you decide to be in the study, I will ask you to go to a website and follow the directions to learn about systems of linear equations. There are four sections that you will go over, each section has a video for you to watch and a question for you to answer. Then there is a practice section after that. This eLesson is different from anything that you have ever used. It is using different types of media, such as graphics, videos, audio with lots of choices for interaction and engagement. At the end you will complete an online survey based on your opinion about what you think about this project. This Activity will only last one class period.

What are the benefits to you for taking part in the study?
If you take part in this study, you might find a method of learning that is useful to you as well and a better understanding of solving systems of linear equations. Taking part in this study may not have direct benefits to you, but it will help me learn how to create learning material that is beneficial for students. The researcher of this study will gain the ability to see your opinion of the lesson based off of the survey.

Can anything bad happen if you are in this study?
I do not expect anything bad happening to you. But if after starting, you do not want to continue, you are fine to do so at any point. If you need to take a break at any time that is ok. This study does not affect your grade so do not worry if you do not finish.

Who will know that you are in the study?
Your participation is anonymous, meaning that no one but I will know that.

Do you have to be in the study?
No, you don’t. The choice is yours. No one will get angry or upset if you don’t want to do this. And you can change your mind anytime if you decide you don’t want to be in the
study anymore. This study will not change your grade or change how your teacher feels about you.

What if you have questions?
If you have questions about the study, you can ask me now or anytime during the study. You can also call me at (909) 223-2692 or e-mail me at jakeagy@cpp.edu or call the faculty advisor Dr. Lotfipour at (909) 869-2255 or email her at slotfipour@cpp.edu. If you have any questions about your rights as a participant in this research or if you feel you have been placed at risk, you can contact the IRB Office at irb-office@cpp.edu or irb@cpp.edu (909) 869-3713. You will receive a copy of this form for your records.

Signing below means that you have read this form and that you are willing to be in this study:

Turn in this form by Friday the 6th of December if you want to participate.

Student prints and signs name

Name of the Participant: (Print your name on the line): ___________________________

Signature of the Participant (Sign on the line): __________________________________

Date:___________________________
Appendix F

Survey

systems of linear equations

Survey Questions
Instructions: Please read instructions and choose your option.

Question Title
1. Was the website easy to navigate?
   - Extremely easy
   - Very easy
   - Somewhat easy
   - Not so easy
   - Not at all easy

Question Title
2. Would you like to have more lessons like this?
   - Yes
   - No

Question Title
3. Did the training cover ...?
   - Too much information
   - Too little information
   - Right amount or information

Question Title
4. Did you experience any of the following while going through the program? (Please select all that apply.)
   - Website did not display properly on desktop
   - Too many pop-ups
   - Pictures, videos or buttons did not work or showed up
   - Pages loaded too slowly
   - Navigating the program was confusing
   - Other (please specify)

Question Title
5. How organized was the course?
   - Extremely well-organized
   - Very well-organized
   - Somewhat organized
   - Not so well-organized
   - Not at all organized
6. Was the pace of the material presented in the project ...
   - Too fast
   - About right
   - Too slow

7. Did the quizzes help you understand what each lesson was trying to teach you?
   - yes
   - no

8. Would you prefer to learn from a project like this instead of learning from a textbook?
   - Strongly agree
   - Agree
   - Neither agree nor disagree
   - Disagree
   - Strongly disagree

9. Would you prefer to learn from a project like this instead of learning from a lecture?
   - Strongly agree
   - Agree
   - Neither agree nor disagree
   - Disagree
   - Strongly disagree

10. Is there anything you would like to be added or changed in this project?