A Study of the Self-Efficacy of Personalized Learning

as a Remediation Tool in Algebra

by

Caroline Andrea Savio-Ramos

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Gary Bitter, Chair
Ray Buss
Jane Legacy

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ABSTRACT

Over the past 25 years, efforts have been made to integrate technology into teaching and learning. In particular, the personalized learning approach has sought to leverage technology to deliver instruction that is adaptive to the learner and personalized learning environments were used as tools in tailoring instruction to match learner needs. Typically, personalized instruction has been delivered using technology, such as the computer. However, little research has focused on using personalized learning as a tool for remediation. The goal of this study was to empirically investigate the efficacy of personalized learning in Algebra as a remediation tool. This study used a mixed-methods approach to analyze satisfaction with the learning environment, perception of and attitudes toward the content being delivered, and the reported overall experience and the personalized experience in the context of two versions of a computer-based multimedia Algebra learning environment. A total of 117 high school students in grades 10 through 12 participated on a voluntary basis. They had previously taken an introductory Algebra course and were now enrolled in a different math course. The students were assigned to one of two conditions: (a) the computer-based multimedia learning environment on the personalized learning platform known as Personalized Learning and (b) the same learning environment without the Personalized Learning platform. In addition to completing a pre- and post-test, participants were administered attitudinal surveys. Results indicated no knowledge gains in either group at the post-test assessment. Further, analyses by gender and race also did not reveal any significant differences among the groups. However, survey results indicated one significant finding: the students exposed to the personalized learning environment had more positive perceptions towards personalized learning than towards the overall experience with the learning environment.

Implications for these results and further goals for this line of research are discussed in greater detail within the context of personalized learning, user experience, and social aspects of learning. This work also provides opportunities in helping educators choose adequate tools for teaching and delivering instruction tailored to learners' needs.

DEDICATION

I dedicate this work to my husband, Luiz Ramos, who has shown me love and support throughout this whole difficult process, even when we were halfway around the world from each other during those difficult 3 ½ years. This dissertation is also dedicated to the loving memory of Sofia and Lila. Thank you for your companionship and unconditional love. Until we meet again.

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INTRODUCTION

Over the last few decades, as technology has improved and become more readily available to consumers, schools and educational institutions have increasingly turned to technology as a way of delivering instruction. As the rise in popularity of personal computers (PCs) grew, schools experienced the introduction and implementation of PCs and educational software as tools to aid in curriculum development and instruction. As a result, facilitation of instruction was guided in such a fashion so as to take advantage of newer, emerging technologies. With the increased availability of computers over the last 35 years and the availability of the Internet to the average consumer over the last 25 years, schools have strengthened their commitment to use technology in enhancing instruction and delivery of curriculum (McIntosh, Lucyshyn, Strickland-Cohen, & Horner, 2014; Parkin, Hepplestone, Holden, Irwin, & Thorpe, 2012; Strayer, 2012). A resulting effect of the increase in technology availability has been the way in which instructional material evolved. One of these changes encompassed the use of computers as interactive teaching devices which adapted to the learner based on the learner's responses. In a world where education has been traditionally "one-size-fits-all," adaptive systems afforded the possibility of having learning be customizable, or personalized.

As class sizes continued to increase (U.S. Department of Education, 2015), teachers and instructors were having a difficult time providing personal help to each student. Since more and more schools are turning to technological solutions in an effort to enhance instruction, this study investigated the efficacy of a personalized learning environment and its role in providing remedial instruction that was tailored to each individual learner.

Overview of the Problem

In what is known as the "2 sigma problem," prior research results indicated on the average, student performance increases by two standard deviations when administering individual instruction in the form of tutoring instead of standardized instruction that is typically found in the everyday classroom (Bloom, 1984). Nevertheless, individual instruction requires time and resources many schools and educational institutions did not provide. Instruction has been limited to a certain number of hours in a day. This, combined with the ever-increasing class size, proved to be a big challenge as teachers were asked to deliver more with fewer resources. Limited resources were forcing the type of instruction delivered to students to be that of an "assembly line" teaching style (Rasberry, 1991), which has been measured via some form of standardized testing. The No Child Left Behind (NCLB) Act of 2001 (Bush, 2001) has sought to quantify learning by holding schools accountable for student performance through the use of standardized testing and, later on, by having federal funding tied to these test results in what has been known as the Race to the Top (RTTT) program (U.S. Department of Education, 2009). NCLB and RTTT also assumed learning was standardized and could be measured using a standardized test, when in the end, there was no substitute for knowing one's subject, which was partly a matter of experience, unquantifiable skill and "of far too great importance to be solved by standardized metrics" (Muller, 2015; Ravitch, 2014). Although a large number of students have been taught via standardized instruction and assessment, such conditions leave little room for taking into account students' individual needs. School districts across the United States, however, have proposed plans for implementation of personalized learning through the use of technology-based learning tools. Nevertheless, only a limited number of schools have implemented these tools (Gallagher, 2014) and this has been attributed to a lack of empirical understanding of success, concerns, and characteristics of technology-based personalized instruction.

The concept of personalized learning has been evolving along with the introduction of emerging technologies and their ubiquitous nature. Schools that offered a personalized approach to learning have been better able to connect with students, find ways to engage them, keep their attention, and help them to capitalize on their strengths as learners (McClure, Yonezawa, & Jones, 2010; Yonezawa, McClure, & Jones, 2012) by including a focus on profiles that enabled each student to be known by instructor, progress based on demonstrated knowledge and skills instead of seat time and have tailored and flexible learning environments (Bill and Melinda Gates

Foundation, 2014). Although research showed individualized and personalized instruction may result in better learning, more research is needed in studying the following: (a) whether personalized learning is a viable solution for remediation in instruction, (b) whether personalized learning tools are being appropriately and efficiently used, as is the challenge with emerging technologies, (c) its efficacy in delivering instruction and (d) whether suggestions can be made for more appropriate uses.

Purpose of the Study

One of the main purposes of this study was to explore whether a personalized learning system could successfully be used to increase algebra competency when used as a remediation tool in a high school setting. Subsequent questions focused on the participants' perceptions and levels of satisfaction in terms of their learning experience, attitudes towards mathematics, perception and levels of satisfaction in regard to their experience using the software and, where applicable, perception of the personalized learning experience.

Prior to this study, personalized learning was not in use by the school district. The school did not have a mathematics curriculum or textbook in place. Technology was available in the form of a computer laboratory and a laptop cart on wheels (COWs). Several teachers and their high school students were invited to participate in the study, which was conducted for approximately one month, after which data collected from the learning environments were analyzed quantitatively and qualitatively. Specifically, this study was aimed at exploring whether the personalized learning experience could be a promising resource to bridge the gap between learning and engaging interactive experiences.

Two Versions of a System

Two versions of a computer-based learning environment were used for this study. At the company's request, the identity of the software, publisher and parent company are being kept confidential. One version of the software presented lessons in a linear model, meaning that the software did not adapt to the learner's responses. The second version of the program was the same software built upon an adaptive platform giving it the capability of delivering questions tailored to learners based on their responses, thus giving them a personalized experience. The goal of this personalized learning-infused version was to provide students with a personalized pathway through course material, allowing them to focus on those specific activities that optimized their time on task and further increased engagement. Success with the personalized product has been seen at the university level where results in a particular mathematics course showed that more students passed the course (75%, up from 64% the previous year) and fewer students dropped out (7% down from 15% the previous year) than in the previous year (Webley, 2013).

In this study, the linear, non-personalized computer-based learning environment (called "Non-Personalized Learning Platform" or NPLP) was compared to its personalized learning-infused counterpart (called "Personalized Learning Platform" or PLP.) This study sought to compare gains in learning on both versions of the software and various dimensions of those perceptions. The research questions and hypotheses are summarized in Tables 1 and 2, respectively.

Research Questions

This study employed a mixed design approach, which explored the research questions summarized in Table 1:

Table 1.

Research Questions by Condition

Q	Research Question	Question Present in Condition?	
		NPLP (control group)	PLP (treatment group)
1	To what extent does personalized learning play a role in knowledge gain when used as a remediation tool?	Yes	Yes
2	How satisfied are students with the overall experience of the program?	Yes	Yes
3	How satisfied are students with the content of the program?	Yes	Yes
4	How satisfied are students with the personalized experience?	No*	Yes

Note. Q, research question number; NPLP = Non-Personalized Learning Platform; PLP = Personalized Learning Platform; *NPLP did not ask about personalization since it was not personalized.

Hypotheses

Based on established empirical work and justification, the following hypotheses were presented in Table 2:

Table 2.

Summary of Hypotheses

Hypothesis			
H_0. No significant differences will be detected among either condition in terms of learning and in terms of satisfaction / experience / content	H_0: PLP *(learning gains)* H_0: PLP *(overall experience)* H_0: PLP *(content experience)*	= = =	NPLP / Control *(learning gains)* NPLP/Control *(overall experience)* NPLP/Control *(content experience)*
H_1. Participants in the PLP condition will achieve higher gains in learning than those in the NPLP control condition	H_1: PLP *(learning gains)*	>	NPLP/Control *(learning gains)*
H_2. Participants in the PLP condition will have had a more positive experience with the system than those in the NPLP control condition	H_2: PLP *(overall experience)*	>	NPLP/Control *(overall experience)*
H_3. Participants in the PLP condition will have had a more positive experience with the content of system than those in the NPLP control condition	H_3: PLP *(content experience)*	>	NPLP/Control *(content experience)*
H_4. Participants in the PLP condition will have positive experience with the personalized nature of system as compared to the overall experience and content experience	H_4: PLP *(personalized experience)*	>	PLP *(content experience)*

Note. H_0 , null hypothesis

Limitations of the Study

This study was conducted in a large, comprehensive public high school with students in grades 10 through 12. Therefore, the results and conclusions of the study may not be exactly replicated with students in other settings, such as in the elementary school or at the university level. In addition, socioeconomic factors among the participants selected were not explored due, in part, to the sample size and makeup of the participant pool. For similar reasons, English language learners (ELLs) were not taken into account. The use of the system on mobile and tablet devices was not explored because the study only employed the use of laptop and desktop computers fitted with a keyboard and mouse.

Organization of Chapters

This dissertation is divided into five chapters. Chapter 1 includes the introduction, overview of the problem, purpose of the study, research questions and hypotheses. In Chapter 2, a review of the pertinent literature including the history of personalized learning, classroom challenges with respect to class size and student need, perceptions of math, remediation and collaborative learning is provided. In addition, this review includes consideration of several aspects of design of educational software and user experience concerns that influence performance. Chapter 3 includes a description of the participant group and methods used in data collection. Chapter 4 includes quantitative and qualitative analyses of the data collected. Chapter 5 provides a discussion of the results, draws conclusions, describes limitations, outlines implications of the study and makes suggestions for further research.

Chapter 2

LITERATURE REVIEW

To better understand how learning has evolved from a one-size-fits-all approach to instruction that is tailored and personalized, it is important to first understand the background behind the technology, pedagogy, metacognition and preferences that affect learning. The literature review begins with a brief history of personalized learning followed by the history of personalized learning and how flipped instruction is often associated with personalized learning. Perceptions of mathematics and attitudes towards learning, learning styles and preferences, and remediation are addressed. Finally, issues affecting user experience are discussed in the context of usability concerns, which may interfere with learning.

Personalized Learning

Traditional teaching and learning of core subjects, such as mathematics, typically has involved homework assignments using problem sets or questions from textbooks. Since the advent of personal computers and their use in both homes and in the classroom, computer-based instructional media (i.e. educational software and more recently, discussion boards, web sites, blogs, and other internet-based tools) have been created to be used as instructional and learning supplements. However, most of these solutions have been comprised of a “one-size-fits-all” approach to teaching and learning. Likewise, the problem sets and educational software have not taken individual learner needs into account. For these reasons, adaptive systems began to emerge. As with many tools in education, there were many ways in which computers and technology have been effectively employed to improve upon teaching and learning practices.

Personalized learning has been used as far back as the 1920s when Helen Parkhurst created the Dalton Plan, which aimed to create a balance between a child’s talent and the needs of the community (Parkhurst, Bassett, Eades, & Rennie, 1924). Specifically, its first objective was to tailor each student’s program to his or her needs, interests and abilities (Dewey, 1922) and to allow every school child to have the opportunity to freely choose a series of activities, already predisposed by the teacher, to fully improve intellectual, social and moral growth (Claparède &

Meylan, 1967). These were only ideas and theoretical practices that did not require any form of technology, including mechanization. Practices that were mechanized with earlier technology to achieve competencies based on the history of responses of the learner were utilized as early as the 1930s (Corbett, Koedinger, & Anderson, 1997). By the 1960's, researchers had already moved beyond systems that presented instruction in a pre-determined fashion, which employed some form of technology. These types of systems were considered to be adaptive in nature, adjusting as necessary to learners' needs in an effort to move towards a more student-centered approach to learning (Hwang, Sung, Hung, Huang, & Tsai, 2012). It was not until the 1970s that the term "personalization" in the context of educational science was introduced and coined by Victor Garcia Hoz (Hoz, 1972).

Although a challenge existed in using technology because computers lacked the human, personal interaction and responsiveness found in their human instructor counterparts, computers became more complex as technology evolved and were able to provide interactive experiences with instant feedback. Specific intelligent tutoring systems (ITSs), which were computer systems with the ability to provide immediate and customized feedback to learners (Psotka, Massey, & Mutter, 1988), contained animated conversational agents that spoke in natural language conveying human-like communication (Fu, 2014), gave feedback based on user-inputted responses and made instant recommendations based on user responses. The term "intelligent tutoring system" was coined by Sleeman and Brown (1982) and was used to describe a computer-aided instructional system whose emphasis was placed on the student to learn by doing in addition to representing the learner's knowledge. An ITS provided a personalized learning environment because it adapted the delivery of educational material according to learners' needs as indicated by their responses given on assignments and assessments. The ITS's ability to provide personalized learning support and feedback to help individual learners improve their learning performance based on personal information, profiles, or learning portfolios have played a major role in learning (Walonoski & Heffernan, 2006). ITS have been the most widely known forms of adaptive learning tools, which provided a personalized learning experience with feedback to help individual students improve their learning performance based on responses or learning portfolios.

According to Tucker (1997), computer-based instruction has shown potential to attain similar or better training outcomes than traditional face-to-face instruction. Educators, researchers, businesses, trainers, and psychologists have attempted to find computer-based instructional programs that met learners' needs and maximized learning experiences (Bartley & Golek, 2004). Every learner was tasked with completing a set of competencies as a way of showing mastery of a subject. The success of these computer-based programs has depended on the learners' abilities to learn new skills of the workforce, technological adaptability, increased productivity, and cost and efficiency (Hategekimana, 2008). This goes back to the "one-size-fits-all" approach where all learners in a class completed activities that were similar or identical to each other. Examples included problem sets, quizzes, and tests. In accounting for different learner needs, learning styles, and speeds at which learners showed mastery, learner preferences have been examined to better understand these issues (Hwang et al., 2012). Educators have suggested teachers and course designers should pay special attention to the learners' styles of learning and tailor the interventions accordingly (Coffield, Moseley, Hall, & Ecclestone, 2012). Personalized learning has been employed as an approach that tailors curriculum and instruction through the use of adaptive learning to meet these learning needs.

The personalized learning system used in this study was an adaptive learning technology system that allowed for building adaptive learning applications within its platform. This type of technology has demonstrated the capability to deliver a personalized experience by continuously assessing student performance and allowing teachers to identify each student's strengths, weaknesses, and monitor progress to give students feedback and tailor instruction. Because its concepts were identified at defined levels, the system is able to make customized recommendations based on students' needs. Data were generated in real time and were sent back to the system, which in turn made recommendations for improvement. Its infrastructure was constructed to provide personalization for any learning product, in any context. Prior studies conducted using personalized learning technology at the university level have shown that after two semesters of use, course withdrawal rates dropped by 56% and pass rates went from 64% to 75% with half of the students finishing four weeks early (Oxman, Wong, & Innovations, 2014). In another remedial mathematics study at a large university, the pass rates for the courses increased from 70% to 87% in the first semester of using a personalized learning platform (Oxman et al., 2014). A third study conducted during summer school showed that after five weeks, 85% of students who had been placed into developmental mathematics at the onset of the program passed into credit-bearing courses (Oxman et al., 2014).

Designing a learning environment where existing linear multimedia learning modules were enhanced via an adaptive learning platform allowed for a new product to be designed that could leverage personalized learning - a tool that has the potential of becoming a key feature of learning. Personalized learning content has been recognized as being one of the most important features of educational systems (Tseng, Chu, Hwang, & Tsai, 2008). Personalized experiences in learning have been achieved via a variety of means with one of the most popular ones occurring via inverted instruction, or flipped instruction. The notion of employing technology to introduce students to course content outside of the classroom so that students can engage in learning at a deeper level inside the classroom is known as flipped instruction (Baker, 2000; Collins, de Boer, & van der Veen, 2001; Gannod, Burge, & Helmick, 2008; Lage, Platt, & Treglia, 2000; Strayer, 2009, 2012).

Flipped Instruction

In recent times, there has been a trend for instructors to turn to the model of the “flipped classroom” where lectures have been delivered as a video and completed as homework. Class time has been reserved for projects and group work. The rationale was that lectures completed as homework allowed learners to watch at their will and at their own pace with the ability to replay sections and discuss what they have watched online with their peers via forums, chats, or other forms of social media. At the conclusion of the lecture, learners were given questions to check for understanding, which provided the instructor with an understanding of the video’s effectiveness for each learner. Using this information enabled the instructor to provide personalized attention during face-to-face class time meetings.

The phrase “flipped classroom” was coined by two chemistry teachers, Jonathan Bergmann and Aaron Sams (Bergmann & Sams, 2012, 2014). In an effort to accommodate students who traveled to attend sporting events or could not keep up with the pace of classroom instruction, Bergmann and Sams partnered to record lectures and posted them on YouTube. By having students watch the lectures before class, Bergmann and Sams freed up class time for hands-on, collaborative learning activities. Students’ long-term retention of knowledge, motivation and course completion rates dramatically improved. After experiencing the success that the students were having using this method of instruction, Bergmann and Sams have worked to promote flipped learning as an alternative to traditional, lecture-based classrooms (Bergmann & Sams, 2012).

In the traditional pattern of teaching, students listened to lectures or lessons, took notes, and were administered quizzes and tests in class while they were tasked with reading textbooks and working on mathematical problem sets for homework. In a flipped classroom, students watch lectures and lessons at home, which were typically prepared by the teacher using technology (Ronchetti, 2010). During class time, students applied what they learned from these lessons in solving problems. The teachers’ role in the classroom became one of a facilitator, rather than one who imparted the initial lesson in person.

Before flipped classrooms, there were auto-tutorials, team learning, peer instruction, inquiry learning, Just-in Time Teaching, blended classrooms, hybrid courses, and process-oriented-guided inquiry learning (Herreid & Schiller, 2013). According to Fulton (2012), the flipped classroom had many advantages including allowing teachers to have better insight into student difficulties, learning styles, and ease of customizing and updating the curriculum at any given moment. In doing so, classroom time was used more effectively and creatively. In addition, teachers using the flipped classroom model reported seeing increased levels of student achievement, interest, and engagement (Fulton, 2012; Strayer, 2009).

Instructional video and podcasts have been shown to have a positive influence on three main areas: student attitudes (Bolliger, Supanakorn, & Boggs, 2010; Fernandez, Simo, & Sallan, 2009; Hill & Nelson, 2011; Holbrook & Dupont, 2011; Lonn & Teasley, 2009), student behavior (Boyle et al., 2013; Chester, Buntine, Hammond, & Atkinson, 2011; Edmunds, Thorpe, & Conole, 2012; McCombs & Liu, 2007) and student performance (Alpay & Gulati, 2010; Crippen & Earl, 2004; Traphagan, Kucsera, & Kishi, 2010; Vajoczki, Watt, & Marquis, 2008). Herreid and Schiller (2013) found that all of these conditions made the use of video podcasts favorable for their use in the flipped classroom. Prior studies on the use of video podcasts in both chemistry and mathematics flipped classrooms further supported this idea (He, Swenson, & Lents, 2012; Kay & Kletskin, 2012).

The flipped classroom model has demonstrated the ability to be flexible in its use of technology appropriate for "21st century learning" (Fulton, 2012). Instructors surveyed on flipped instruction reported satisfaction because there was more time to spend with students on authentic research, students got more time to work with scientific equipment that was only available in the classroom, students who were absent could watch the lectures anywhere, the method "promotes thinking inside and outside of the classroom" and students were more actively involved in the learning process, (Fulton, 2012; Herreid & Schiller, 2013). Although another study found that students in the flipped classroom were, at first, less satisfied with how the classroom structure oriented them to learning tasks, in this case statistics, they became more open to cooperative learning and innovative teaching methods (Strayer, 2012).

According to Hamdan, et al. (2013), four elements were essential to the flipped classroom: (a) rearrange the classroom for more group activities and allow students discretion to decide what and when they will learn; (b) intentionally shift the role of instructor from an expert who has complete control of the classroom environment to a facilitator/guide who helps students to solve problems independently; (c) use active learning strategies known as "intentional content" to shift the focus to a learner-centered pedagogy.

(d) Employ collaborative learning environments, personalize instruction and maximize interaction between students and instructors instead of resorting to lecture-based instruction and work with other educators to hone the craft of flipped instruction. Advocates of the flipped method of instruction almost universally agree that its success is not measured by the instructional videos on their own, but how they are integrated into an overall approach (W. Tucker, 2012).

Nearly every level of education from middle school to graduate and professional programs has adopted the model of the flipped classroom. In higher education, this has been increasingly evident as many courses have been becoming online or hybrid - a blend of in-person instruction combined with an online element. One of the most prevalent examples of flipped instruction in higher education has been the Massachusetts Institute of Technology (MIT) Open Courseware (OCW) initiative, which opened access to information that was previously only available to university students (Bishop & Verleger, 2013). Continuing this trend, an MIT alum founded the Khan Academy, which has released an extensive library of videos and practices in many languages (Khan, 2015). Inspired by Khan Academy, two Stanford Professors opened up access to online courses in 2011. Afterwards, open online educational initiatives such as Coursera and EdX began offering courses from many universities around the world that agreed to open their content. These videos have constituted a collection of online learning material known as massively open online courses (MOOCs) (Siemens & Downes, 2008).

Researchers have verified cases where flipping instruction improved nearly every positive educational indicator: student learning and knowledge gains, compliance with educators' instructions, instructors' satisfaction, and even student attendance (Allen, 2014; Aronson & Arfstrom, 2013; Bergmann & Sams, 2012, 2014; Valenza, 2012). Lage, Platt and Trelia (2000) theorized that "inverted instruction," a precursor to flipped classroom, was more effective than the traditional lecture as it engaged all learning types by using multiple teaching formats.

To hold students accountable for watching materials before class, educators suggested administering an assessment, such as a quiz, immediately following the lecture content (Allen, 2014; Benjes-Small & Tucker, 2013; Leibiger & Aldrich, 2014). These assessments allowed both instructors and students to identify students' difficulties, and allowed time in class to review and address such concepts. Further, class time was utilized by instructors to formatively assess student learning (i.e. using student response systems such as clickers or via the use of computer based instruction that was personalized) and offer appropriately tailored feedback almost instantaneously (Butt, 2014; Herreid & Schiller, 2013; McLaughlin et al., 2014).

Attitudes and Perceptions of Mathematics

Understanding the relation between emotions and learning has gained momentum over the years (Verkijika & De Wet, 2015). Students have demonstrated a tendency to shy away from science and mathematics courses such as Algebra (Soh, Arsad, & Osman, 2010; Woolnough, 1994). The U.S. Department of Education (2008) reported that mathematics anxiety has been recognized as an impediment to mathematics achievement, which has widespread consequences on the achievement of students (Beilock, Gunderson, Ramirez, & Levine, 2010). Many students have held a negative attitude towards these subjects because of the complexity of the subject matter (Gilmore, Wilkerson, & Hassan, 2012). In addition, fear inhibited students from drawing connections between mathematics and real-life experiences (Gilmore et al., 2012). It is not only students who possess a fear of mathematics. Prior studies documented that students feared mathematics due to previous learning experiences and feelings of inadequacy and incompetence in mathematics (Brady & Bowd, 2005; Bramald, Hardman, & Leat, 1995; Scarpello, 2007). In addition, negative feelings of mathematics expressed by teachers have led to less confidence overall which has hindered actual teaching performance (Bates, Latham, & Kim, 2013) and contributed to students' negative experiences.

Although technology has been thought to be the silver bullet that could revolutionize education, prior research has indicated that computers are neither a cure-all for problems facing the schools nor mere fads without effects on student learning (Schacter, 1999). The real question is what can be done to address negative attitudes towards mathematics and whether or not a personalized learning environment will motivate students and change negative perceptions? In a previous study conducted using a non-personalized system, Pierce et al. (2007) found that attitude toward learning mathematics with technology was positively correlated with confidence in using the technology among high school boys. Among high school girls, the only relation found was a negative correlation with mathematics confidence. Empirical evidence indicated positive emotions such as engagement and concentration were related to enhanced learning (Pekrun, Goetz, Titz, & Perry, 2002; Sabourin & Lester, 2014), whereas negative emotions such as frustration, anxiety and boredom were associated with adverse effects (Meyer & Turner, 2006; Sabourin & Lester, 2014). This produced the question of whether attitudes can be changed for the better through a personalized learning experience.

Although teachers have used several classroom strategies to reduce mathematics anxiety (Sun & Pyzdrowski, 2009), students may still be faced with mathematics anxiety on their own and often did not know what to do (Verkijika & De Wet, 2015). One effective means through which students learned mathematics independently was through educational games (Abdullah, Abu Bakar, Ali, Faye, & Hasan, 2012; Devlin, 2011). Combining mathematics computer games with the potential of a device such as a brain-computer interface device in providing real-time neuro-feedback on physiological arousal acted as a technological solution for effectively monitoring, training, and reducing mathematics anxiety (Verkijika & De Wet, 2015).

Personalized solutions in any form, including games and puzzles, have been used in conjunction with learning strategies. The use of learning strategies such as comprehension, creation, and memorization and their effectiveness has been found to distinguish higher performing students from those that are lower performing (Kitsantas, 2002). Learning strategies have also aided students in reducing a task into its basic elements and then reorganizing these elements into a meaningful whole (Cheema & Kitsantas, 2014). Instructors have modeled and taught students to match strategies to their learning goals and encourage students to monitor their effectiveness (Cheema & Kitsantas, 2014; Kitsantas, 2002; Zimmerman & Kitsantas, 1999). Desirable characteristics of computer based learning environments - in particular, ones that were delivered online - included taking into account learning strategies that utilized multimedia elements. These elements included simulations and manipulatives that used the dimensions of online learning to create positive attitudes while supporting different types of learning experiences (Meylani, Bitter, & Legacy, 2015).

Learning Styles, Preferences and Social Aspects of Learning

In the past decade, researchers have studied various issues relating to learning styles in order to better understand the model of learning and learning preferences of students (Hwang et al., 2012). Keefe (1987) defined an individual's learning style as a consistent way of functioning that reflected the underlying causes of learning behavior. It was also speculated that learning style was both a student characteristic indicating how a student learned and liked to learn and an instructional strategy informing the cognition, context, and content of learning (Keefe, 1991). Learning styles were also likely to influence how students learned, how instructors taught, and how both interacted (Reiff, 1992).

Recently, researchers have analyzed classroom strategies and learning styles as a factor in motivating students. It was found that the most important individual predictors of learning strategy preference in mathematics were perceptions of one's own mathematics self-efficacy and teacher support in mathematics lessons (Cheema & Kitsantas, 2014). Boys and girls were found to differ in terms of their learning style preferences with girls emphasizing control strategies and boys emphasizing elaboration strategies.

Several studies have been conducted to develop personalized learning systems based on various student models, such as the learning portfolios, preferences, and knowledge levels of students (S.-L. Wang & Wu, 2011; Y. Wang & Liao, 2011). Additionally, the use of learning styles as one of the parameters of providing personalized learning content by constructing a system that takes student knowledge levels and learning styles into account has been established (Hwang et al., 2012; Tseng et al., 2008). Among those factors that affected the delivery of personalized learning content, learning styles have been recognized as being an essential element (Filippidis & Tsoukalas, 2009).

Coffield, Moseley, Hall, & Ecclestone (2004) indicated teaching biased towards any one of the extreme poles of the model would disadvantage some learners and that a reliable and valid instrument which measures learning styles and approaches could be used as a tool to encourage self-development, not only by diagnosing how people learn, but by showing them how to enhance their learning. Further, it was concluded that student learning performance could be improved if proper learning style dimensions were to be taken into consideration when developing adaptive learning systems (Filippidis & Tsoukalas, 2009; Hsieh, Jang, Hwang, & Chen, 2011; Tseng et al., 2008).

Outside of individual preferences for learning, many people have learned via some form of social mediation (Salomon & Perkins, 1998). Daily observations and experiences suggested a certain amount of learning took place beyond the confines of the individual mind and involved social aspects (Salomon & Perkins, 1998). In classrooms, we have seen evidence of this in project based learning (PBL) where students in a physics class may be tasked with building a model to launch a projectile requiring precise measurements and using cooperative learning strategies involving group work, which served a socially mediated instructional strategy that afforded teachers the ability to address both intellectual and social learning goals (Coates & Mayfield, 2009). Social mediation has also been seen through a sociocultural (Salomon & Perkins, 1998) lens where learning has been regarded as participation in a social process of knowledge construction (Cole, 1995; Greeno, 1997). The learner and social mediation interactions have been distributed over the entire social system rather than possessed by the learner (Salomon & Perkins, 1998).

Remediation

There have been times when students completed a course, but did not learn the material, did not retain what was learned in a course, or required extra assistance to achieve expected outcomes and competencies. Remediation was intended to assist students in learning the material necessary to achieve these expected outcomes. A defining characteristic of a learner needing remediation has been that one showed under-preparedness, regardless of the reason why. This type of education has been designed for any learner.

Currently, most remedial courses have been delivered via traditional, semester-long courses. Some of these courses have employed cohort models, which grouped students together according to ability. Other courses were modularized and targeted student skills. Many of these solutions were administered via computer-based instruction. More recently, this computer-based instructional method of delivery has included self-guided courses that have been adapted to skill set deficiencies. A review of studies on remedial education was conducted and the results indicated programs showing the greatest benefits with relatively rigorous documentation either (a) placed students that needed remediation into mainstream college level courses with additional support, (b) provided modularized courses allowing remedial students to complete coursework, or (c) offered contextualized remedial education within occupational and vocational programs (Zachry Rutschow & Schneider, 2012). Other solutions included the use of online courses as a way of providing remedial courses for students. However, completion of online courses was lower across almost every group of students compared to face-to-face remedial instruction (Jenkins, Jaggars, & Roksa, 2009). In addition, students enrolling in online remedial courses were less likely than face-to-face students to continue on to college-level coursework in the same content area (Jaggars, 2013). Moreover, the problem ensued that these solutions were still tailored to the model of “one size fits all” and did not account for individual differences within learners.

User Experience Design and Usability concerns

Although computer based instructional programs have been shown to be more effective than traditional learning (Ponce, Mayer, & Lopez, 2013), it was only in recent years that program designers began paying attention to affective factors, such as user experience (Norman, Miller, & Henderson, 1995). User experience (UX) was defined by the international standard on ergonomics of human system interaction (ISO 9241-210, 2010) as a person’s perceptions and responses that resulted from the use or anticipated user of a product, system, or service. Over the years, software has evolved with the visual improvement of computer graphics from more rudimentary two-dimensional figures to more visually appealing graphics. In addition to visuals, cues, menus and interfaces were designed in a way that allowed optimal experiences for the user. The effectiveness of visual environments for learning depended on a variety of design factors, including the information design and interaction design of the materials and the level of cognitive load they imposed (Plass, Homer, & Hayward, 2009). Visual environments for learning have been shown to depend on the emotional design of multimedia instruction because this involves making the essential elements in the lesson's graphics more appealing (i.e. rendering them with human-like features) and with colorful visuals (Um, Plass, Hayward, & Homer, 2012). Previous work by Mayer and Estrella (2014) provided consistent evidence that redesigning multimedia lessons to incorporate some of these emotional design principles substantially improves learning outcomes.

Usability has been a term that was used interchangeably with UX. Usability was traditionally associated with work systems and described in terms that related to task driven activities where the user has little discretion (Sim, MacFarlane, & Read, 2006). According to Bevan, Kirakowski, & Maissel (1991), the term "usability" was coined in the early 1980s as a replacement to the phrase "user friendly," which resulted in having a different meaning. The ISO ergonomics definition given in the context of usage and user orientation stated usability was "The effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in a particular environment" (Brooke, Bevan, Brigham, Harker, & Youmans, 1990). Ease of use determines whether a product can be used and how it will be used.

Since usability and ease of use were highly subjective, it required testing in various areas. At the conclusion of completing a task, it was beneficial to have users answer some questions about the level of difficulty of the task, ease of use of the system, previous experience and interaction preferences. These questions preceded evaluation of performance on a task.

Evaluation of usability was also conducted keeping in mind the process, outcome, affect (POA) approach, which emphasized "What the user does," "What user attains," and "How user feels" (Dillon, 2001). Observing the way users interacted with different systems helped researchers understand how the user moved through the information space. What the user attained at the end of the interaction helps determine what it meant for the user to feel accomplished. How the user felt helped to identify meaningfulness of interaction.

Prior research conducted on software usability and learning has shown that both ‘observed’ and ‘self-reported’ measures of fun in using educational software and the findings yielded that both metrics were informative (Read, MacFarlane, & Casey, 2001). In another study, Sim, MacFarlane, & Read (2006) found the educational software products evaluated in their study all had usability problems and that the users (children ages 7-8) appeared to have less fun when their interactions had more usability problems. As a result, usability mattered to users in terms of fun, yet no correlation was found between learning and measures of usability and fun with using the software.

Summary and Research Questions

Although it has been difficult to reach a large number of students via face-to-face instruction, technology has afforded instructors the opportunity to provide instruction in an efficient way. This instruction has traditionally not been tailored and has been regarded as one-size-fits-all instruction. Personalized learning systems have provided a way for instructors to deliver content tailored to individual learners regardless of the number of students in a class. Although these systems provided rich multimedia environments, real-time data, instant feedback, and the opportunity to access lectures on a home computer, these systems were still very new and there was little literature supporting their use as a remediation tool to fill this gap in the literature and to provide evidence in context with personalized learning, this study was conducted to answer the research questions, previously described in Table 1 and restated, here.

1. To what extent does personalized learning play a role in knowledge gain when used as a remediation tool?

2. How satisfied are students with the overall experience of the program?

3. How satisfied are students with the content of the program?

4. How satisfied are students with the personalized experience?

Chapter 3

METHODOLOGY

Participants and Design

A total of 117 high school mathematics students in grades 10 through 12 were recruited and volunteered to participate in this study, which took place during the spring of 2015 in the last month of the school year. The participants were recruited from a large comprehensive high school in the southwest United States with a total population of 3,700 students in grades 9 through 12 (see Appendices H,I and L.) Participant ages ranged from 15 to 18 years, with an average age of 15.89 (*SD* = 0.98) and median age of 16 years old. The gender makeup consisted of 62 (53.0%) male participants and 55 (47.0%) female participants. The ethnic and racial makeup can be seen in Table 3 and was collected using a survey (see Appendix A.)

Table 3.

Ethnic and Racial Makeup of Participants

Racial / Ethnic Makeup	Number of Participants	Percentage of Participants
White / Caucasian	35	29.9%
Hispanic / Latino	39	33.3%
Black / African American	17	14.5%
Asian / Pacific Islander	3	2.6%
Native American	7	6.0%
More than one race	5	4.3%
Other	1	0.9%
Do not wish to provide	10	8.5%

Note. Data collected using the demographics survey in Appendix A

The participants came from regular-level courses, which means they were exposed to basic algebra in a previous introductory algebra course and were not selected from honors or advanced placement levels. Participant course enrollment at the time of the study was comprised of the following, summarized in Table 4.

Table 4.

Participant Mathematics Course Enrollment

Mathematics Course	Number of Participants	Percentage of Participants
*Algebra / Geometry mixed course	19	16.2%
Geometry	49	41.9%
Algebra 2	49	41.9%

Note: *The Algebra / Geometry mixed course is a course that is offered to 10th grade students who have previously been enrolled in Algebra 1 and need extra help. It covers half of the regular Geometry course. Data collected using the demographics survey in Appendix A

along with students, teachers were also recruited to participate in the study on a voluntary basis and received monetary compensation in the form of gift cards varying in amount, as well as free access to the computer-based learning environment for the following school year (see Appendix J.) Approximately 50 students who completed the assignment were randomly chosen to receive monetary compensation in the form of a $10 gift card. The participants were made aware of this prior to commencing the study during the pre-test with the intent of encouraging participation in the study (see Appendix K.)

The participants were assigned an ID number. Because they were mostly minors under the age of 18 and no identifying information was collected, the Institutional Review Board determined that the protocol was considered exempt pursuant to federal regulations 45CFR46 (1) and can be accessed in Appendix M. Data from all participants, including matched pre- and post-test scores (see Appendices B and C), were included in the analyses. Two incomplete responses, four invalid responses, and five participants who did not take the post-test were removed from the final analyses, which were therefore based on 106 eligible respondents. In using data for analyses, the gender breakdown consisted of 58 (55%) males and 48 (45%) females.

Materials

The materials and equipment required for execution of this study included access to a computer laboratory, laptop carts, the learning environment/system for the activity and pre- and post-test assessments (Bicer, 2015). The learning environments (Bicer, 2015) consisted of two versions of a computer-based multimedia software whose name was being kept confidential. For simplicity, the two versions were named the Personalized Learning Platform (PLP) and Non-Personalized Learning Platform (NPLP). Both versions contained identical problems and entailed software for first-year algebra lessons on quadratic equations. This study used NPLP as the control condition and PLP as the personalized learning condition.

Prior knowledge of Algebra was assessed via a pre-test and content-readiness test, which was created by Bicer (2015) (see Appendix B.) The pre-test was comprised of 20 questions and was divided into two sections: the content-readiness portion and the questions on the subject matter. In addition to the pre-test assessment, demographic information was collected from each participant (see Appendix A.) At the conclusion of the experiment, a post-test was administered, which consisted of ten questions on the subject matter that were similar to the questions on the pre-test (see Appendix C.) Attitudinal surveys were also administered to evaluate and measure student user satisfaction (see Appendices D, E and F.) The users in the PLP condition were asked about preference issues concerning the personalized learning environment on the PLP (see Appendix F.) These surveys used a Likert scale ranging from 1= *Strongly Disagree* to 4 = *Strongly Agree*.

This study employed a mixed-method design that included a between-subjects factor and a within-subjects factor, where subjects were randomly assigned to either the NPLP condition or the PLP personalized learning condition. Random assignment was used to minimize any threats to internal validity. The multimedia content and subject matter on each platform were identical.

The computer-based learning environments. The computer-based learning multimedia software provided mathematics teachers with an instructional solution promoting mathematics mastery through dynamic, interactive learning. The learning environment was developed as an alternative to print material that has been most commonly found in classrooms. This digital solution took advantage of the online environment and technological tools, such as the interactive whiteboard, already in place in classrooms. By having the learning environment available for use in classrooms on computers and interactive whiteboards, small groups and individual students could be assigned tasks and assignments. The learning environment, itself, was flexible in allowing teachers to differentiate instruction due to the nature of the assignments.

In this study, the learning environment was divided into three modules called "Module 1: Introduction to Quadratics", "Module 2: Solving Quadratic Equations" and "Module 3: Graphing Quadratic Functions". In the NPLP condition, the modules contained 5, 6, and 13 activities, respectively, which were infused with multimedia content and embedded questions (see figures 1 and 2 for the NPLP condition.) In the PLP condition, each module consisted of at least 6 activities (see figures 3, 4 and 5 for the PLP condition.) At the conclusion of each activity in the NPLP condition, a short quiz was available for learners to assess their progress and move ahead to the following activity. In the PLP condition, quizzes were embedded throughout the modules (see figure 4 for a sample of a quiz on the PLP condition.)

Two treatment groups were established using this software. Of the participants, 56 (47.9%) constituted the PLP condition, which provided the personalized learning experience as compared to 61 participants (52.1%) who constituted the NPLP condition.

The Non-Personalized Learning Platform. The NPLP condition consisted of the computer-based learning environment without the personalized component and contained multimedia content (i.e. short videos and embedded examples with quizzes). All of the learners in this condition went through the same lessons in the same sequential order, regardless of achievement scores on the embedded problems and quizzes (see figures 1 and 2 for screen shots of the NPLP condition.)

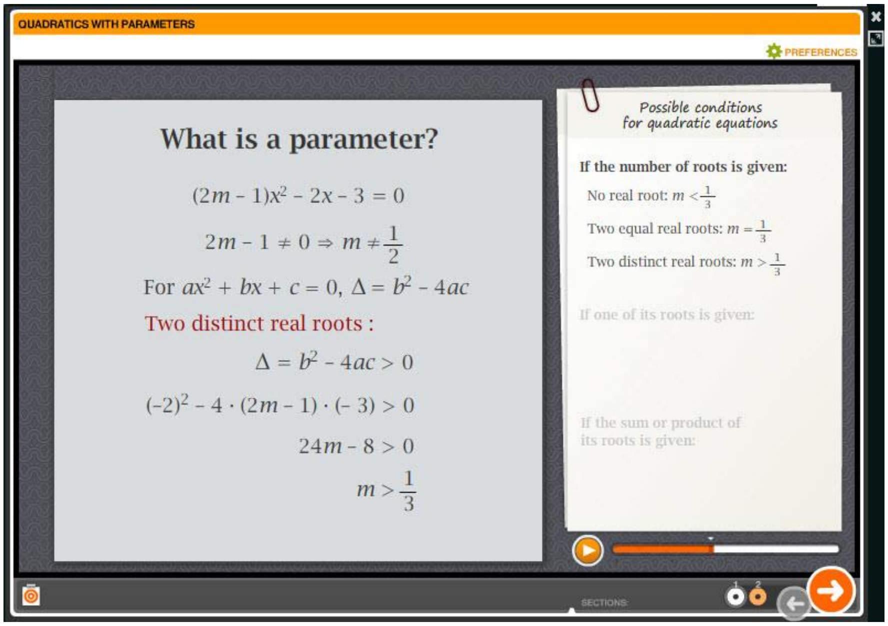

Figure 1. Screenshot of a sample lesson in algebra in the NPLP condition

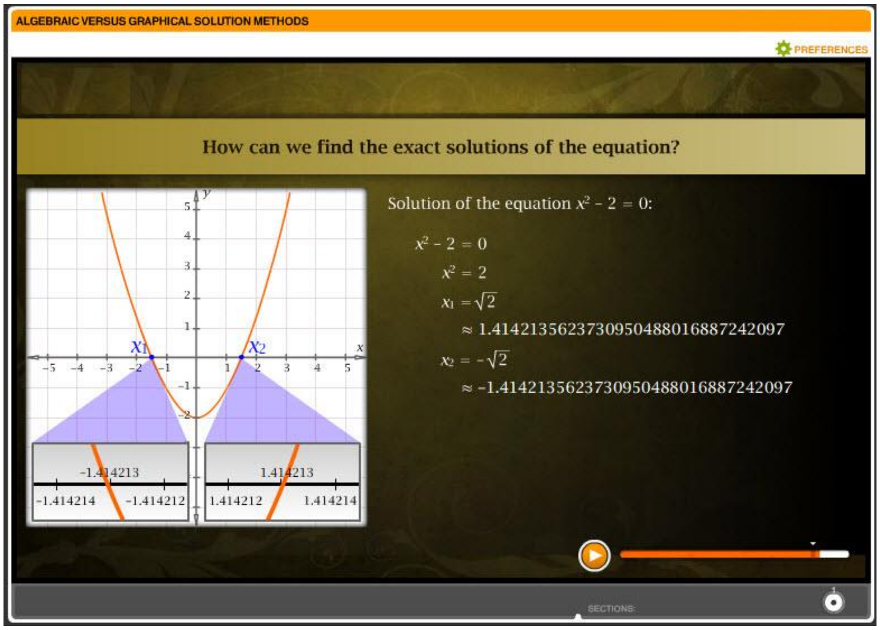

Figure 2. Screenshot of graphics used in the NPLP condition

The Personalized Learning Platform. The computer-based learning environment on the personalized learning platform delivered the same content received by the NPLP group. However, in this version, the learning environment was adaptive and personalized because a profile was created for every learner. Each learner's profile was sustained with assessment data as a new module was completed on the platform. Using this data, the learner's profile was consistently updated and analyzed using data from other learners in the platform's repository. Recommendations for the appropriate module based specifically on this data were then made. Both instructors and students were able to access this data. From the student or learner point of view, the platform showed the predicted score(s) for the upcoming assignment, current mastery level on assignments completed, current mastery level on a specific topic and the likelihood of the learner completing an assignment on time. From the instructor's point of view, all of the data about the learners were aggregated. This allowed the instructor to make informed decisions and tailor instruction, accordingly. See figures 3, 4 and 5 for screen shots of the PLP condition.

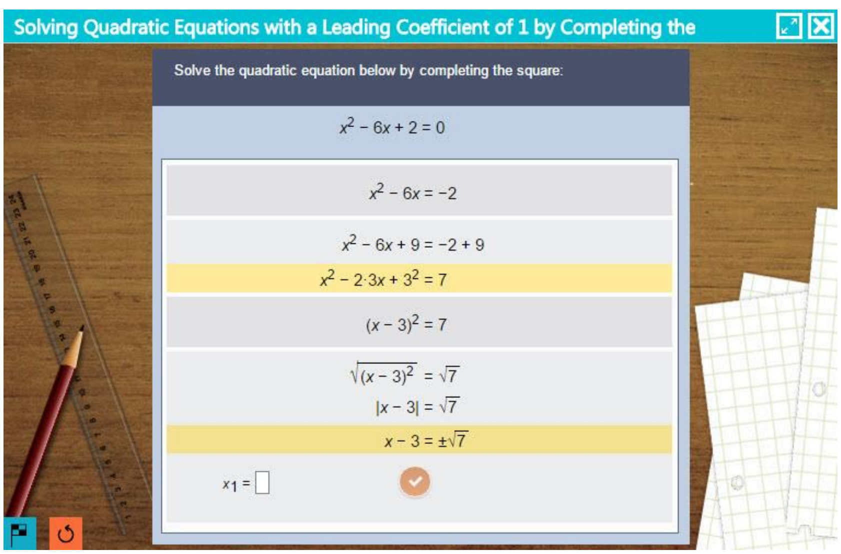

Figure 3. Screenshot of the assignment in the PLP condition

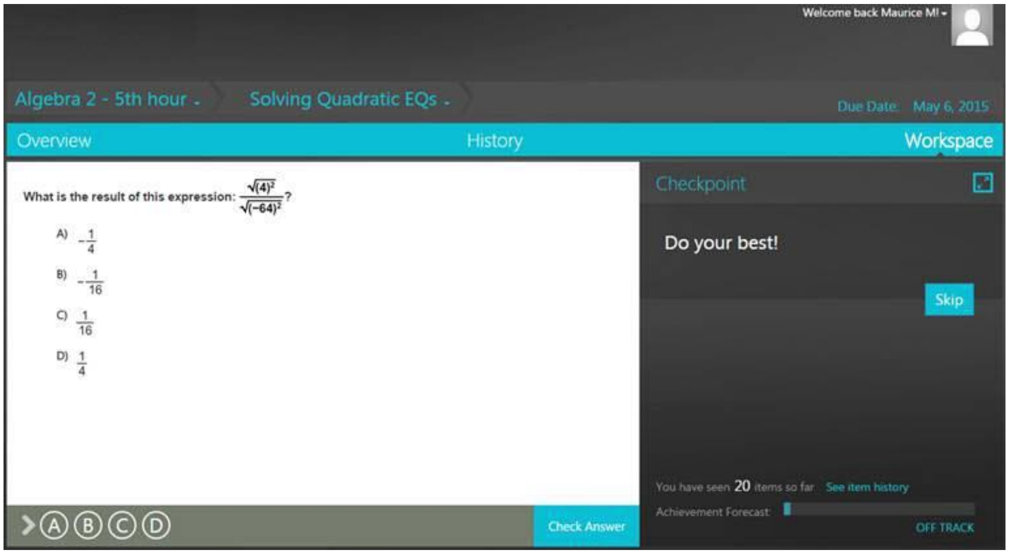

Figure 4. Screenshot of the PLP condition with progress bar and workspace.

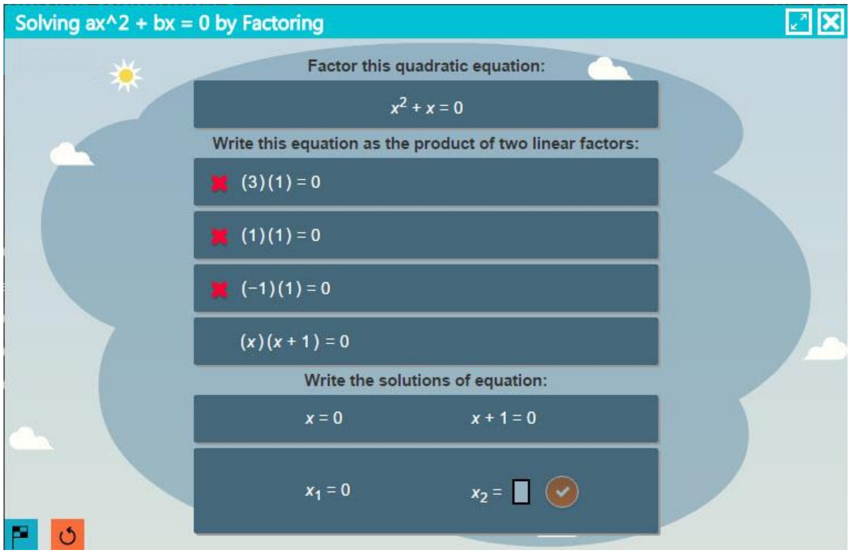

Figure 5. Screenshot of the PLP condition.

Measures

Pre-test assessment and content readiness instrument. A paper-based pre-test assessment containing 20 multiple-choice questions was administered to the participants to measure prior content knowledge of quadratic equations in Algebra. The first 10 questions constituted the content-readiness test, which showed how prepared participants were in terms of algebra knowledge in order to be able to grasp or recall quadratics. The results of the content-readiness test were later used as a covariate during data analysis. The second set of 10 questions was used in establishing levels of prior knowledge with respect to quadratic equations. Each question on the pre-test had a score of 1 for the correct answer and 0 for the incorrect answer. A maximum score of 20 points could be achieved on the pre-test. The pre-test was scored both by the experimenter and her colleague to ensure inter-rater reliability. In addition to the pre-test, a demographics survey was administered to capture information about age, gender, grade, ethnicity, and mathematics course enrollment. See Appendix B for the Pre-Test and Content Readiness Test.

Post-test assessment and surveys. A post-test assessment consisting of 10 questions on quadratic functions was administered to the participants after the intervention activities. The post-test questions were similar to those on the pre-test assessment, but used different numerical values and were presented in a different order. Correct responses were given a score of 1 and incorrect responses were given a score of 0. Refer to the Post-test Assessment in Appendix C.

The surveys administered were created by Bicer (2015). For simplicity, these surveys assessed attitudinal data and consisted of the following: the overall experience of using the system, the experience of the content put forth by the system and in the Personalized Learning condition only, the adaptive experience of that particular platform. The surveys and post-test assessments were scored by the experimenter and her colleague to ensure inter-rater reliability. Seven questions were about the overall experience of the system. Four questions were about the experience with the content on the system. Eight questions were given to the participants in the Personalized Learning condition regarding the personalized learning experience provided by the system.

Data Analyses

This mixed design study was incorporated both quantitative and qualitative analyses. Data was analyzed using a triangulation method (Creswell & Clark, 2007; Fielding, 2012; Jick, 1979; B. Johnson & Turner, 2003; Palinkas et al., 2013), which allowed the quantitative and qualitative data to be collected and analyzed separately. The results of those analyses were then brought together and used to draw conclusions, which were discussed in detail in the subsequent chapter. The description of the variables and covariates involved in the experiment have been summarized in Table 5, below.

Table 5.

Table of Dependent and Independent Variables, and Covariates

Dependent Variables	Independent Variables	Covariates
Gains in knowledge / post-test results	NPLP Condition	Perceptions towards math (prior to treatment)
Survey responses on content experience	PLP Condition	Learning abilities and preferences
Survey responses on overall experience		Learning styles
Survey responses on personalized experience		

Qualitative and Quantitative Data. The quantitative data consisted of pre-test, content readiness, and post-test scores. The quantitative data addresses the first research question (see Table 6, below) and is further discussed in detail in the subsequent chapter. The qualitative data consisted of participants' responses to the survey questions, which have been discussed further, below. The survey questions served as instruments in addressing the remaining research questions, which were described in Table 6. Since coding data helped simplify and made analyses more efficient because they were labeled and retrieved efficiently (Basit, 2003; Hayes &

Krippendorff, 2007; D. R. Thomas, 2006), survey data were coded and quantified to be able to perform the appropriate analyses.

Table 6.

Research Questions and Analytic Methodologies

Research Question	Data Set	Analyses
To what extent does personalized learning play a role in knowledge gain when used in remedial education?	PLP and NPLP pre-test, content readiness and post-test scores	Descriptive Statistics Repeated measures ANCOVA
How satisfied are students with the overall experience of the program?	Survey results	MANOVA Repeated measures ANCOVA
How satisfied are students with the contents of the program?	Survey results	MANOVA Repeated measures ANCOVA
How satisfied are students with the adaptive experience? (Personalized Learning platform, only)	Survey results	Repeated measures ANCOVA

Overall experience survey. The Overall Experience Survey consisted of seven questions, which were created by Bicer (2015). These questions, which have been provided in their entirety in Appendix D, focused on attitudes towards the program. More specifically, they queried the participants about how satisfied they were using the program during class, for homework, as a study tool and how effective they felt the tool was in giving practice topics. Other questions on this survey asked about how the program “flowed” from question to question and whether or not the participants would recommend this program to a friend. In addition, participants in the PLP condition were asked one additional question about whether or not they perceived the software to be personalized.

Content experience survey. The Content Experience Survey consisted of four questions, which were also created by Bicer (2015). These questions, which have been provided in Appendix E, focused on attitudes towards the content that the program provided. The questions asked participants about the level of engagement of the content put forth by the system and how helpful they felt the interactive modules were in teaching the concepts. Other questions included the level of satisfaction studying math with this particular program as compared to other programs and how often the participants needed to refer to the ‘How to Complete’ information in order to solve the problems needed to complete the module.

Personalized Learning Experience Survey. The Personalized Learning Experience Survey, which was only administered to participants in the PLP condition, consisted of eight questions, which were also created by Bicer (2015). These questions, which have been provided in Appendix F, focused on perceptions of the personalized nature of the PLP condition. The questions asked participants whether the order in which the materials presented made sense, how good of a job did the program do in recommending materials, the level of difficulty of the recommended materials, how well the items related to the assignment goals, and the helpfulness of the progress bar in the program.

Open-ended Questions. At the very end of the attitudinal surveys, participants were administered four open-ended questions. The participants assigned to the PLP condition were administered a fifth question relating to personalization in learning. These findings related to these questions have been further discussed in subsequent chapters. The open ended questions were only analyzed by the experimenter and used in conjunction with prior research to support hypotheses. Refer to Appendix G for the full list of open ended questions.

Procedure

The study was conducted in both a computer laboratory on desktop PCs and in a classroom equipped with a laptop cart. At the beginning of the study, participants were asked to sign a consent form. The participants were assigned an ID number in order to be (a) randomly assigned to either the PLP or NPLP condition and (b) to keep their identities confidential. Prior to taking the pre-test, the participants answered a questionnaire aimed at capturing demographic information. The pre-test was then administered.

The intervention activity consisted of various lessons on quadratic equations. There were three sets of modules and students had one week to complete each set. The modules were divided into multiple sub-lessons. The students worked individually and spent about 1h 30min on module one, 1h 45min on module two and 30min on module three.

Participants engaged in the study over the course of four weeks. They performed the tasks involving quadratic equations and worked through them until completion. After each weekly assignment, the teachers reviewed the data that was populated by both the Personalized Learning and Non-Personalized Learning Platforms. At the conclusion of the four weeks, the post-test assessment was administered, and then followed by the attitudinal surveys. Table 7 summarized the sequence of events of the experiment.

Table 7

Summary of the experiment.

Week	Material	Actor	Actions
1	Consent form	Students & Teachers	signed the consent forms
1	Demographics survey	Students	completed the demographics survey
1	Software / Learning environment	Students & Teachers	completed training / walkthrough of how to interact with the software
1	Pre-test and content readiness test	Students	completed individual pre-test and content readiness test.
2	First module & assignments	Students	completed the first module and its assignments
3	Second module & assignments	Students	completed the second module and its assignments
4	Third module & assignments	Students	consisted of completing the third module and assignments
4	Post-test & surveys	Students	completed post-test and attitudinal surveys where they answered questions about their overall experience, experience with the content and the personalized experience, if applicable.
4	Open-ended questions	Students	completed open-ended survey
4	Debriefing	Students, Teachers & Administrators	were debriefed
4	Rewarding	Students that completed the assignments	were randomly drawn to receive a $10 gift card
		Teachers	received gift cards in varying amounts

Chapter 4

RESULTS

One of the goals in this research study was to determine the main differences in learning between a personalized versus a non-personalized learning experience. Another goal was to analyze the user experience to determine the main differences in student-user attitudes and satisfaction between these different environments.

Quantitative survey data involving the PLP and NPLP conditions were analyzed using descriptive and inferential statistics with statistical software package SPSS 22. Qualitative interview and survey response data were coded and analyzed manually.

Research Question 1: To what extent does personalized learning play a role in knowledge gain when used in remedial education? Results from a mixed-design repeated measures analysis of covariance (ANCOVA) showed no effects for between- and within-subjects effects. The between-subjects effect was not significant, $F(1, 103) = 0.02$, $p < .91$. Similarly, the within-subjects effect was not significant, $F(1, 103) = 0.87$, $p < .36$. Moreover, the time (pre- to post-test scores) by condition (NPLP vs PLP) interaction effect was not significant, $F(1, 103) = 3.15$, $p < .08$. Finally, the ANCOVA assumption of equal slopes was met because the time versus readiness score (covariate) was not significant, $F(1, 103) = 0.12$, $p < .74$. The means and standard deviation are shown in Tables 8 and 9.

Table 8

Mean and Standard Deviation of All-Inclusive Secondary School Students on Knowledge Measure

	Mean	Standard Deviation
Pre-Test	2.86	1.61
Post-Test	3.15	1.38

Table 9

Mean and Standard Deviation of Secondary School Students on Knowledge Measure by Platform Type

	Pre-Test		Post-Test	
	M	SD	M	SD
NPLP	2.71	1.57	3.33	1.39
PLP	3.02	1.64	2.96	1.36

Note. M and SD denote Mean and Standard Deviation, respectively; *NPLP,* Non-Personalized Learning; PLP, Personalized Learning

An ANCOVA was performed by gender and revealed no significant differences between male and female subjects $F(1, 103) = .00$, $p < .98$. Refer to Table 10 for the means, standard deviation and ANCOVA results. The means, standard deviation, and results of the ANCOVA broken down by gender and condition are shown in Table 11.

Table 10

Overall Analysis of Covariance Results of Secondary School Students on Knowledge Gain by Gender Without Taking Condition Into Account

	Males		Females				
	M	SD	M	SD	$F(1, 103)$	p	η^2
Overall	.31	.14	.21	.12	.00	.98	.00

Note. M and SD denote Mean and Standard Deviation, respectively. *F*, frequency (degrees of freedom); *p*, probability value, η^2, partial eta squared or effect size.

Table 11

Analysis of Covariance Results of Secondary School Students on Knowledge Gain by Platform and Gender

	Males		Females					
	M	SD	M	SD	*df*	*F*	*p*	η^2
NPLP	.36	.14	.29	.12	52	3.08	.085	.05
PLP	.25	.14	.33	.11	48	4.07	.050	.07

Note. M and SD denote Mean and Standard Deviation, respectively. *F*, frequency; *df*, degrees of freedom; *p*, probability value, η^2 partial eta squared. *NPLP,* Non-Personalized Learning; PLP, Personalized Learning

An ANCOVA was performed by ethnicity and revealed no significant differences in gain between the participants $F(7, 97) = 0.73$, $p < .63$. Refer to Table 12 for the means, standard deviation and ANCOVA results. The means, standard deviation, and results of the ANCOVA presented by ethnicity and condition are also shown in Table 12.

Table 12

Overall Analysis of Covariance Results of Secondary School Students on Knowledge Gain by Ethnicity and Platform Type

	White		African American		Hispanic		Native American		Asian		Mixed Race		Other		Decline Answer						
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	df_1	df_2	F	p	η^2
O	.29	.13	.26	.16	.33	.13	.35	.19	.43	.15	.34	.12	.30	0	.31	.11	7	97	.73	.63	.05
NPLP	.30	.12	.31	.10	.33	.16	.50	.14	.50	.14	.32	.17	.30	0	.31	.09	7	46	.82	.57	.11
PLP	.28	.13	.21	.20	.33	.11	.20	.00	.30	0	.36	.05	0	0	.30	.16	6	43	.79	.57	.10

Note. M and SD denote Mean and Standard Deviation, respectively. O, overall meaning not taking condition into account; NPLP, Non-Personalized Learning; PLP, Personalized Learning; *F*, frequency (degrees of freedom); *p*, probability value, η^2, partial eta squared.

Research Question 2: How satisfied are students with the overall experience of the program? and Research Question 3: How satisfied are students with the contents of the program? A multivariate analysis of variance (MANOVA) was conducted to analyze difference on overall experience and content experience between the NPLP and PLP groups. The results of the MANOVA were not significant, $F(2, 103) = .13$, $p < .88$. The means, standard deviation and results from the MANOVA are shown in Table 13.

Table 13

Gains in Means, Standard Deviations, and MANOVA Results of Secondary School Students' Content and Overall Experience by Platform Type

	Content Experience		Overall Experience				
	M	SD	M	SD	F(2, 103)	p	η^2
NPLP	1.95	0.698	1.77	0.673	.13	.085	.003
PLP	1.90	0.618	1.69	0.801	.13	.059	.003

Note. M and SD denote Mean and Standard Deviation, respectively. NPLP, Non-Personalized Learning; PLP, Personalized Learning; F, frequency (degrees of freedom); p, probability value, η^2, partial eta squared or effect size.

Research Question 4: How satisfied are students with the adaptive experience? A repeated measures analysis of variance (ANOVA) was conducted to analyze differences among overall experience, content experience, and personalized learning experience for the PLP group. The results from the repeated measures ANOVA showed that, for the students in the PLP group, the difference in mean scores between perception of the personalized learning experience (M = 2.03, SD = 0.638) and the overall learning experience (M = 1.69, SD = 0.801) were statistically significant, $F(2, 49) = 6.65$, $p < 0.003$, $\eta^2 = 0.21$, (see Table 15) with a large effect size based on Cohen's criteria (Olejnik & Algina, 2000). Post hoc analyses showed the means for overall experience and personalized learning experience were significantly different. The means and standard deviation are reported in Table 14.

Table 14

Means and Standard Deviation of Secondary School Students' Content, Overall and Personalized Experience on the Personalized Learning Platform

	Content Experience		Overall Experience		Personalized Experience	
	M	SD	M	SD	M	SD
PLP	1.90	0.618	1.69	0.801	2.03	0.638

Note. M and SD denote Mean and Standard Deviation, respectively; PLP, Personalized Learning

Table 15

Repeated Measures Analysis of the Variance on Students' Perception of Personalized Learning Compared to Overall Experience on the Personalized Learning Platform

	Overall Experience		Personalized Experience				
	M	SD	M	SD	$F(2, 49)$	p	η^2
PLP	1.69	0.801	2.03	0.638	6.65	0.003*	0.21

Note. M and SD denote Mean and Standard Deviation, respectively. *F*, frequency; *df*, degrees of freedom; *p*, probability value where p <.05 denotes significance*, η^2, partial eta squared or effect size; PLP, Personalized Learning

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Results from Open Ended Survey Questions

The analyses in this section were conducted to answer five open-ended questions (refer to Appendix G): 1) What did you like best about the platform? 2) How do you think the system can be improved and please name at least one useful feature to add? 3) What would you change about the system? 4) Using three words, describe your experience with the system. 5) How was the material personalized to you? (Personalized Learning platform, only).

NPLP, What did you like best about the platform? Students offered responses that praised the high quality multimedia graphics of the system, such as "[I enjoyed] the animated portion, they were entertaining." Issues addressed included the style in which the lessons were presented. One such response included "I like the idea of [the system] but [I} am personally not a fan. It might work well for someone that likes to be taught in this way but I personally like to ask questions and can't do that with [the system]." Other responses included "I don't like learning on the computer. It's hard for me to learn like that" and "I didn't really like anything about it. It's useful, but I would rather have a teacher." Moreover, respondents suggested confusion arose in terms of instruction they received. .These comments included: "I didn't really like it because it was confusing and not very straightforward on what to do" and "The instructions were convoluted. Repeating instructions when it didn't make sense the first time is counterproductive. I learned nothing."

Although many of the responses were negative, some users offered praise. These responses included, "I like how they review hard topics because I forgot them," "I liked that it explains everything to you in a matter of minutes and it helps me stay focused. It can also repeat the lesson if you forget or don't know how to do it," and "I like the way it was explaining to me how to work a problem." Satisfaction was also expressed about the different methods of solving a problem, "I liked how it showed you how to do a problem and then you got to try it" and "What I liked was that it gave us different problems to look at because they are solved differently." The users also appreciated the convenience of being able to access the lessons at home, "I love studying at my own pace" and "What I liked best was how you're able to access this program at home [to] review the content at any time."

PLP, What did you like best about the platform? Responses were divided between positive and negative reception of the Personalized Learning Platform. Positive reactions were primarily focused on the visuals and aesthetics of the program. Comments included "The videos and models were good. You can see what they are trying to help you understand," "I really enjoyed the visuals because they explained the content really well," and "It did give me a new experience to work with." Users also offered responses that indicated they liked the interactive explanations provided in the platform when they claimed, "It had many interactive explanations on how to do a problem," "I liked how the problems were set and what to do when you don't understand," and "I liked how you can see where you made mistakes."

Negative comments included preferences for teacher instruction as opposed to computer-based learning as noted by on participant to noted, "I like to learn from a teacher in real life". Other negative feedback arose from frustration at feeling confused. These comments included "It was all too overwhelming and confusing," "It was hard and very confusing and "I did not like the system because it was too fast and complicated to complete." The repetitive nature and lack of ability to skip ahead was brought up in many survey responses. These included, for example, "the program would not let you go on until the problem was correct." Responses from other students indicated that the users liked the idea of the system but not the actual system itself, "I like the idea" and "I liked the actual idea of the program, but not the actual program."

NPLP, How do you think the system can be improved and please name at least one useful feature to add? Responses from most students included the ability to skip ahead on videos already watched. One user suggested a mastery test that would allow skipping of a particular lesson. "Allow for skipping by taking a mastery test. If you get a passing score, you can skip the lesson. If you fail, you must do the lesson." Many responses also asked for better explanations or more in-depth explanations. These comments included, "When you can't get an answer right, it shouldn't just give you the answer. It should help you through the problem," "I think the system can be improved by being more specific like giving an example and explaining it." One particular respondent suggested, "It would be beneficial to have a help button that explains it more."

The topic of gamifying the system and making it more entertaining was a recurring theme in the comments. Users suggested improvements such as making the learning platform more entertaining and engaging. Specifically, students suggested, "The system can be improved by giving hints or clues during the section. Make it more entertaining and fun, especially for high school," "One useful feature you can add to the system could be adding more excitement," "Make it more fun by adding a game," and "make the system more appealing to students. Maybe add a game."

In students' responses, usability issues in not knowing how to proceed were prevalent. The users did not know what to do when a lesson was over because there was no indicator of where to click to go on to the next section. There was not a clear indicator on the screen prompting them to take the quizzes and assessments at the end of the lesson. Frustrations expressed with respect to this issue included: "I found myself not knowing what parts were more important than others so when it came to testing, I was lost. While doing anything interactive, I was like 'what do I do? It isn't telling me anything.' Put a support system in so people can ask questions," and "The tests need to pop up. I didn't even know I had to do them."

PLP, How do you think the system can be improved and please name at least one useful feature to add? Students' feedback on this question for the Personalized Learning Platform also involved making the system more fun and easier to understand. One particular student commented, "Adding a better understanding of how to correctly do the problem." Other respondents called for more step-by-step examples of how to solve the problems as illustrated in the following comments, "the program was hard to keep up with and needs more examples / I think the system could improve by giving more information and explaining more / the system should include a shorter explanation to lessons and show what we did wrong". Terminology was confusing to students who suggested, "have better vocab[ulary]". Not many kids understand all the math terms right away." Respondents also expressed frustration about the inability to skip videos and problems that were too challenging to solve. For example, respondents indicated, "Having a help button or something when we get the answer wrong would be helpful instead of 'please try again,' Clarify what's being asked several times," "It would be cool to add a button to skip the audio and not go back," and "Have a little failsafe where if a student gets a problem wrong multiple times, just give them the right answer and then go back over it."

There were instances where the users ran into bugs in the system. The progress bar at the bottom of the screen was not accurate for some users. They preferred not to have it and to instead have the computer let them know what needs to be completed. "Show us what needs to be done next instead of having the bar. Also let the computer know where we are." Bugs in the software also arose and were addressed by students and included, "I wish it didn't have as many bugs or glitches" and "I think it could use a report a problem bar or a tab so that at the next update, the problem could be fixed."

NPLP, What would you change about the system? Many of the responses centered on making the system more entertaining, less repetitive, clearing up instructions, and adding more examples to make understanding easier. These suggestions included "Maybe adding more examples where the system works through the problem thoroughly," "Make the instructions more reliable to teens so that they understand the problems better," and "Have students be able to ask it questions if they are confused."

PLP, What would you change about the system? One of the suggestions that was prevalent for the Personalized Learning Platform was having the system highlight mistakes that the user was making and show steps for solving the problems. "When a problem is wrong, highlight what is wrong. Show the correct answer and why. Then give them a similar problem again. That way, you don't get stuck and have no chance of moving on," and "if you don't get a question right after a certain time, you can move on to another concept and come back." In addition, users expressed the desire of being able to move on to another concept or questions by skipping over a video or difficult problem as illustrated in the following quote, "If you don't get a question right after a certain time, you can move on to another concept and come back." Other suggestions involved making the videos and examples easier to comprehend, and making the level of questions easier and building to something more difficult as noted in the following, "have different and harder skill levels" and having the system available to use on a mobile platform as suggested in the following, "you could do them on smartphones instead of a laptop."

NPLP and PLP. Using three words, describe your experience with the system?

Both the Non-Personalized Learning and Personalized Learning Platforms contained similar adjectives to describe each platform. "Boring" was a frequently used adjective to describe both systems. Other words such as confusing, difficult, and stressful were widely used by the participants in the Non-Personalized Learning condition. "Frustrating" was a term used in the Personalized Learning condition to describe that platform. Other terms used were "complicated", "confusing", "hard" and "glitchy" due to the number of bugs in the Personalized Learning Platform. Some positive adjectives were used. One person described the Non-Personalized Learning platform as being "interesting" and "somewhat helpful." Other adjectives used in the Personalized Learning Platform included "new," "unusual," and "OK."

PLP, How was the material personalized to you? In the Personalized Learning Platform only, participants were queried about how the material was personalized to them. Responses varied from negative to positive. Negative responses included, "I did not understand most of it, so I don't think it was very personalized." Positive responses were more descriptive and included, "I now know about plugging in the x values for a function graph. Thank you for giving me the opportunity to try out your new system," "If I didn't understand the problem, it would go over it with me a lot," and "My material was personalized through the frequency of problems I understood and problems I didn't understand."

Summary. Although no significant differences were found among the PLP and NPLP groups in terms of knowledge gains, the participants in the PLP condition did like the personalized aspect of the platform more than their overall experience with it. Based on the comments, many participants felt frustration towards the PLP and NPLP platforms due to the problems being difficult, confusing, not knowing what to do next and feeling that the interface was "buggy." Nevertheless, participants did feel that it was something new, unusual, interesting, and they liked how it went over material and the overall novelty of having used such a system. Discussion of these results is addressed in the final chapter.

The number of instances of keywords appearing in student open ended responses are summarized in tables 16 and 17, below.

Table 16

Instances of Keywords Appearing in Open Ended Responses in NPLP Condition

N	Positive Keywords	Negative Keywords
32		boring
15		make it more fun
12		confusing
7		hard, difficult
5	interesting	did not understand material
5	reviewed a lot	add games
4	interactive	glitches
3		allow us to skip

Note. N denotes the number of times this response appeared

Table 17

Instances of Keywords Appearing in Open Ended Responses in PLP Condition

N	Positive Keywords	Negative Keywords
24		boring
14		confusing and not clear, frustrating
11		didn't understand
10	liked personalized experience	could have been more helpful
8		repetitive and long
7		make it more fun and interesting
5	interesting	
4		bugs
2		prefer a real teacher

Note. N denotes the number of times this response appeared

Chapter 5

DISCUSSION

The purpose of this study was to investigate the extent of the role personalized learning played in knowledge gains when used as a remediation tool for Algebra. The main finding in the results revealed that participants presented with the personalized learning experience perceived a higher level of satisfaction with the personalized nature of the learning environment than with their overall experience with the program. In this chapter, a discussion of the findings relative to the research questions, survey results and open ended survey questions is presented. Limitations, implications and future directions are also discussed.

Findings for Research Question 1

To what extent does personalized learning play a role in knowledge gain when used as a remediation tool? The purpose of this analysis was to investigate whether or not a personalized experience would provide a more meaningful context to increase gains in learning when used as a remediation tool. An analysis of the pre- and post-test scores with respect to condition showed there was very little gain in scores and not enough to constitute any significant findings. This outcome suggests that the participant's gain in learning from experiencing a personalized treatment did not differ from the non-personalized condition. Analyses with respect to gender and gender and condition interactions did not yield any significant differences among the groups. The two largest groups of students consisted of Caucasian and Hispanic students. These groups, together, constituted more than half of the participants. Therefore, since there were fewer participants of other races to compare against, a valid comparison was not possible. No significant differences in achievement with respect to gender, which agrees with prior literature that among high school girls, the only relationship found was a negative correlation with mathematics confidence (Pierce et al., 2007).

Open ended questions showed dissatisfaction with the system and a dislike for both the system and the content area. As previously mentioned, prior research indicates that positive emotions such as engagement and concentration can enhance learning (Pekrun et al., 2002;

Sabourin & Lester, 2014), whereas negative emotions such as frustration, anxiety and boredom can have adverse effects (Meyer & Turner, 2006; Sabourin & Lester, 2014). Negative feelings and emotions regarding the subject matter further serves to discourage students and lead them to not perform as well (Andrews & Brown, 2015; Brown, 2014; Network, 2014; Orabuchi, Yeh, Chung, & Moore, 2013). Performance due to dissatisfaction in terms of user experience also serves to hinder completing a task at optimal levels (Albert & Tullis, 2013; Hassenzahl & Tractinsky, 2006; Karapanos, 2013).

One of the biggest challenges in learning involves getting students to appreciate the subject. Generally, strategies employed in teaching include making the content relevant to the learners. Although the visuals of the learning environments were aesthetically pleasing, students may have felt disconnected to the topic of algebra. Examples were very abstract (i.e. finding points on a parabola) and students may have had a difficult time connecting the concept of a parabola to something more tangible. A suggestion for making this abstract concept more concrete for students in helping them understand what a parabola is would have been to superimpose a parabola with its equation on a familiar object such as a satellite dish TV antenna, a contact lens, or a curved mirror used in stores to dissuade shoplifters. Students could also be have the opportunity to propose examples that are familiar to their everyday lives. By doing so, this would allow them to see the relevance of what they're learning and how it is applied to everyday life. In turn, students would feel more at ease and harbor less negative feelings towards something they deem as unknown.

Findings for Research Question 2

How satisfied are the students with the overall experience using the system? An analysis of the question regarding the overall experience of using the system did not yield significant differences between the groups. On a scale of 1 to 4 where 1 was complete dissatisfaction and 4 was complete satisfaction, both means were around 1.9, indicating a lower level of satisfaction. Open-ended survey questions revealed usability issues, which were particularly prevalent on the Personalized Learning Platform. These included the inability to skip forward, bugs in the software, and the lack of functionality for asking questions. Instead, questions are directed at the teacher, peers and in some cases, the experimenters.

Optimal interaction experiences include interfaces that are intuitive or clearly allude to subsequent actions after completing a task and performing fewer clicks to achieve a goal. The ability to customize an experience suited to user preferences also optimizes the user experience. Flexibly adaptive design processes allow educational products to be designed in such a manner that creates a balance between control by designers and easy reconfiguration by users such as teachers, instructors and, in some cases, students (Schwartz, Lin, Brophy, & Bransford, 1999). By allowing more flexibility in setting up the program in such a fashion that allows user-manipulation of visuals and controls, the result could be higher satisfaction rates and better user experience. In turn, having a better user experience may contribute to higher scores in learning.

Findings for Research Question 3

*How satisfied are students understanding the content of the system***?** The results of the MANOVA comparing content experience and overall experience were not significant. Content experience in the Non-Personalized Learning (M=1.95) and Personalized Learning (M=1.90) were relatively low when analyzed on a scale from 1 to 4 with 1 being complete dissatisfaction and 4 being complete satisfaction. Students felt that they did not understand the content on either platform. These results are supported by prior research in student attitude towards mathematics, usability concerns in interacting with the system and in similar responses given on the open-ended survey questions as previously reported in the results.

Prior empirical research backs the claim that student attitude towards mathematics is generally poor. Attitude towards mathematics plays a powerful role in motivating the learning process (Lamar, 2014). Oftentimes, the way that mathematics is presented in the classroom and perceived by students, even when teachers believe that they are presenting it in an authentic and context dependent way, tends to alienate many students from the subject (Barton, 2000; Farooq & Shah, 2008; Furinghetti & Pehkonen, 2002; Lamar, 2014) thus resulting in a more negative perception. By comparison, previous research results show positive attitudes towards learning and towards the content leads students to achievement success.

Frustrations and negative attitudes may arise due to confusion and lack of understanding brought about by unfamiliar notation, wording or symbols applied to something already learned. During the course of the study, one of the mathematics teachers approached the experimenters several times to dispute the responses given to the students by the system. The notation used by the system at times differed from what the teacher taught in class. In addition, the teaching style and method employed by the system was different than that of the teacher(s). Thus, the possibility arises that students may feel frustrated about the system because they were used to learning algebra in a slightly different manner. Because there are so many different teaching styles and learning styles, mismatches in teaching and learning can and do occur (Kapadia, 2008). Open-ended responses on both the Personalized Learning and Non-Personalized Learning platforms also showed student frustration with responses such as "a little confusing and difficult to understand examples," "frustrating, frustrating, frustrating," and "not very understandable". Future work on the content could involve developers of the system partnering with educators to ensure a uniformity of notation in alleviating confusion and is further discussed in this chapter.

The level of the content and the achievement score of 70% required to proceed to the next level was too high, according to the teachers and the students. Many students have different learning styles and are on different levels of learning. These different learner types include sensing, visual, active, and sequential learners (R. M. Felder & Silverman, 1988; Kapadia, 2008; Soloman & Felder, 2005). Prior work by Felder and Silverman proposes the hypothesis that engineering (and mathematics) instructors who adapt their teaching style to include both poles of each of the given dimensions (i.e. both visual and verbal) should succeed in providing an optimal learning environment for students (R. M. Felder & Silverman, 1988; R. Felder, 2004). Taking into account the social/human aspect of learning, a teacher is likely to sense this and make instruction decisions accordingly. It may be more challenging to create a computer based learning system that is able to sense what type of learner is interacting with it. However, using the Index of Learning Styles questionnaire (Soloman & Felder, 2005), a combination of appropriate algorithms and opening up channels of communication between developers and instructors is something that could be performed in the future in order to optimize content delivered to the learner and minimize negative experiences.

Findings for Research Question 4.

How satisfied are students with the personalized learning experience (Personalized Learning condition only)? An analysis of this question revealed an increase in satisfaction score from the overall experience (M = 1.69) to the personalized experience (M = 2.03, p < .003) where 1 indicated complete dissatisfaction to 4 indicating complete satisfaction. Although the question asked about the personalized nature of the system, many frustrations and negative answers were directed at the overall experience of using the system. More neutral and positive user feedback in the open ended portion of the survey revealed responses relating to the frequency that the content was being delivered: "my material was personalized through the frequency of problems I understood and problems I didn't understand", "if I didn't understand it, the program would go over it with me, a lot".

The significant difference in the personalized experience versus overall experience can be attributed to the individualized nature of the feedback given to students by the learning platform. Feedback was also detailed, as opposed to receiving feedback consisting of only "good job", "fair" or "poor". The novelty of having a computer provide detailed feedback could have played a role in higher satisfaction rates compared to the novelty of the program as a whole. Predictive feedback involving how students are slated to score on subsequent modules also bore a novelty effect on the students in that they were curious to know how they would do in the future.

Predictive feedback could, however, serve as a deterrent or be construed as off-putting if the program predicts low scores for subsequent modules. Low score predictions are akin to low expectations. Teachers' expectations for students - whether high or low - can become a self-fulfilling prophecy (Lumsden, 1997; Trouilloud, Sarrazin, Bressoux, & Bois, 2006). That is, students tend to give to teachers as much or little as teachers expect of them (Lumsden, 1997). Lack of cultural synchronization because of misunderstanding, missed communications and low or no teacher interaction results in negative teacher expectations (Irvine, 1990). This may very well be a big contributor to the negative perception of the learning environment, overall. It is important to set the bar high, but not have expectations that are difficult to achieve. After all, expectations and achievement can influence students' future educational behaviors (Khattab, 2015). Since it was difficult to attain the passing score of 70% set forth by the system, many students could have become discouraged and put forth respective effort in achievement.

Keeping expectations in mind, along with leveraging new technologies, it is important when developing new programs to have a goal of encouraging student achievement. Designers are striving to build and support learning environments and solutions that encourage and enable learners to stay abreast and comfortable with new technology, constant change and continual improvement (Martinez, 2001). Older paradigms of learning assume that an instructor is available in the classroom to respond to the students' wide range of questions and complex learning needs. Computer based instruction typically does not provide this due to its design that often overlooks cognitive factors. These factors include how people create, process and store knowledge. Personalized instruction aims at breaking through this paradigm of technology's inability to take into account more intricate learning needs. It allows for individual differences in an attempt to use student-centered approaches to learning (Capuano, Gaeta, Orciuoli, & Ritrovato, 2009; Gilbert & Han, 2002; Kim, 2009; Liu, 2007; Martinez & Bunderson, 2000). In addition, increases in learning activities may lead to increases in learning orientations and higher standards on performance (Samah, Yahaya, & Ali, 2011).

The significant finding of the study between the overall experience of using Personalized Learning and the personalized experience provided is consistent with empirical studies conducted and reported in the current literature. Other research on personalized learning shows that the environment is best applied online via a website, giving optimal conditions for such instruction (Martinez, 2001, 2002; Samah et al., 2011). Personalized learning environments have also given rise to learner satisfaction (Liu, 2007; Martinez, 2001) that will in turn increase learner motivation (Lim, Morris, & Yoon, 2006). These results also support findings on the open ended surveys and in this research question.

Open-Ended Questions Analysis

The open ended questions at the conclusion of the survey provided students with the opportunity to express their thoughts on using the system to learn. These questions were comprised of the following: 1) What did you like best about the system? Please explain. 2) How do you think the system can be improved? Can you please name at least one useful feature to add? 3) What would you change about the system? 4) Using three words, describe your experience with using the system. In the Personalized Learning condition only, the following question was asked: 5) How was the material personalized for you?

Numerous participants indicated that they much preferred having a teacher instruct lessons than rely on a computer to deliver the instruction. In addition, during the course of the study, although students were receiving instruction via the computer, they did ask the teacher, the experimenter and their peers for assistance. This was necessary in that many questions were about troubleshooting on the system, nuances in the learning environment, clarifications on notation and meanings and, in some instances, higher order algebra questions.

Limitations

Limitations of personalized learning exist in that higher order thinking skills cannot be taught outside the classroom (Allen, 2014). This is due to the nature of technology not being able to respond and answer questions as effectively as a human instructor. An example of this is the lack of scaffolding questioning provided by a computer in order to analyze and process abstract questions.

Flipped learning is an example of learning that has become personalized. It is very difficult for students to take ownership for their learning, especially since prior research acknowledges that if students are to succeed in learning STEM topics, which include math, they must learn to navigate and cross the cultural borders that exist between their own cultures and the subculture of science and math (Monteiro, 2015).

Other challenges and limitations presented by computer based personalized learning are that 1) the premise of the system relies on what can be seen as ineffective lecturing in videos, or simply put, a high-tech version of an antiquated instructional method: the lecture (Ash, 2012a). Much of the content and multimedia of pre-recorded lectures may become obsolete in rapidly changing fields (Davis, 2013; Slomanson, 2014). 2) English language learners (ELLs) could feel isolated as would students not having access to a computer at home (Ash, 2012b).

Field versus Laboratory Testing

This study was conducted in a school setting. However, some teachers encouraged their students to complete some of the assignments at home, since the learning environment could be accessed via any desktop or laptop computer with an internet browser. The question lies in whether or not students would interact with the program the same way at home as compared to in school under the supervision of an instructor. Furthermore, do students use computers to complete assignments at home in the same way as they do in school? Many social media platforms and websites are restricted in schools. Some students may turn to social media for help on an assignment. Others may search on the internet and come across a page that is blocked in school, but can access at home. In these examples, students are not interacting with the learning environment and learning experience at school in the same fashion that they would at home. Field testing can be conducted to study how users interact with the learning environment both at home and in school. From there, recommendations for improving the learning environment can be formulated.

Field testing and testing in a laboratory versus a home setting may yield different results in terms of how users interact with a system. In addition, contextual inquiries could be used in learning more about the users and how they interact with the program (Raven & Flanders, 1996) in the setting where they are most likely to use the system. According to Beyer and Holtzblatt, (1997) contextual inquiries involve semi-structured interviews where users are first asked a set of standard questions. Then, the users are observed and interviewed while working in the learning environment. Comparisons are made between responses on the standard questions and observational interview questions. Longitudinal research studies, which involve observation of participants over a period of time both in the field and in a laboratory setting could also yield results about how the software is used at home versus in school.

Social Interaction

The form factor of technologies such as the desktop or laptop computer do not allow for easy sharing of input devices (Billinghurst & Kato, 2002). Regardless, many students were inclined to try to work together in pairs. Many had questions and felt more comfortable asking the teacher or a peer rather than relying on the computer to answer all questions. Prior research has brought attention to the fact that reinforcement of the social interaction component in distance education and blended instruction is the key to the learner's motivation and resolve (Bernard et al., 2004; Dollar, 2000; Ludwig-Hardman & Dunlap, 2003; Palloff & Pratt, 1999). It has also established that rather than increasing the number of support activities to existing courses materials, cooperative and collaborative learning activities should be incorporated, which give learners more opportunities to obtain support from collaborative learning communities (Anderson, Poellhuber, & McKerlich, 2010; Thorpe, 2002). In addition, research also suggests that courses designed using this kind of pedagogical model show retention rates similar to in-person, face to face offerings (Dochy, Gijbels, Raes, & Kyndt, 2014; Fisher, Thompson, & Silverberg, 2005).

Classroom activities should leverage collaborative learning and peer mentoring potential through work completed in groups (Bergmann & Sams, 2014; Crouch & Mazur, 2001) since prior empirical work conducted by Vygotsky has established this as a way to increase student learning (1980). In addition, collaborative assignments encourage participation of students who may be reluctant to ask questions or contribute ideas to class discussions. These results are evident in the model of the flipped classroom (Bergmann & Sams, 2012) and can be translated to personalized learning environments, which are often used hand-in-hand with the flipped instruction.

Implications and Future Research

The results of this study have several implications for the design of personalized learning environments in instruction and learning. Since this study designates the first time that the Personalized Learning platform has been used with this particular learning environment as a tool in remediation, it is only natural that there is room for improvement. Designers of the system would benefit greatly from examining user feedback from students and teachers in designing a system that leverages ease of use, clear instructions, contain a standardized set of symbols and notations commonly used in math courses and the ability for instructors to tailor and customize problems as they see fit.

Since this was the first time that the system was deployed in a school setting, it can be considered a pilot study of sorts. In usability testing, pilot studies are important in establishing what improvements can be made based on how users interact with different systems and what unforeseen issues may arise that are not evident during design and development of such system. A great deal of useful usability data captured can be used in advising future directions of subsequent versions of the learning environment.

In addition to the user experience improvements that can be made to the system, pairing students together in groups of two or three to one of the platforms may yield different results in terms of knowledge gain and satisfaction. In an era where social media has become pervasive and the most popular form of communication among young adults and adolescents (Badr, 2015; Loader, Vromen, & Xenos, 2014; Xenos, Vromen, & Loader, 2014), it is important to keep in mind the notion that humans are social creatures (Gariépy et al., 2014; Lindström & Olsson, 2015) and need human elements in learning (i.e. a teacher or a peer to ask questions and problem solve). Directing attention to learning as a social experience may also lead to scaffolding of learning and higher order thinking. The system is not able to answer questions that involve extrapolation of ideas and complex questions. These questions are explored and answered in a setting that involves other humans, such as in a group or classroom discussion. A suggestion and possible solution is combining the social element of learning with personalized learning. Grouping students in pairs or groups of 3 would allow students to discuss with each other while receiving personalized instruction appropriate for both students. While it would be difficult to differentiate achievement between each individual and receive personalized feedback for each individual student in the group, students could be paired by similar abilities.

Related work carried out by Lawson-Martin and Normore (2005) examined achievement, attitudinal and behavior differences between students completing computer based learning activities in a traditional, individualized format compared to cooperative learning groups. It was found that there is limited effectiveness of computer based learning in addition to students learning better through noncompetitive, collaborative group work than in classrooms that are highly individualized and competitive. As a consequence to these studies and the one conducted in this dissertation, there is a need for further analysis of learning achievement effects of grouping students by ability when using blended learning instruction or simply put, analyzing pairs of students versus individual students. Students may be grouped having similar abilities in order for the personalized system to have more accuracy in tailoring instruction to users at similar levels. The social element of having human contact and wanting questions answered by a human is evident in the open ended responses where several participants said “I’d rather have a teacher available to ask questions than rely on the system to teach me.” Further studies could also show whether cooperative learning not only increases achievement, but attitudes towards math as a subject.

In a previous study conducted by Thomas (2006), attitude towards mathematics and achievement was captured by combining cooperative learning strategies with instruction delivered using an Integrated Learning System (ILS), which is a computer-based instructional system similar to the one employed in this dissertation study. Results from Thomas’ work showed that students using the ILS for mathematics instruction performed better on standardized tests and had a more positive towards math when they worked in cooperative groups than when they worked on the same, individually.

According to Barab et al., (2005), new technologies involving the use of the internet offer much potential as vehicles for intercultural collaborative inquiry, allowing for the development of global perspectives on local issues and to find complex approaches to complex problems. However, technology is yet but a tool that is only as powerful as the user chooses to make it (Barab et al., 2005). As discussed previously, the technology has not proven to be the so-called silver bullet of education. Future research could be guided in the direction of the social aspect that humans employ to interact with each other and with computers. Leveraging the different ways in which humans interact with computers in a social manner could be vital to seeing how technology could be used as a powerful tool in learning.

Students made suggestions on the open ended survey indicating the desire to see games embedded in the software. Making learning “fun” is a very subjective task that would require extensive ethnographic surveying (Barab, Thomas, Dodge, Squire, & Newell, 2004). Nevertheless, concepts of “fun” and “entertainment” intersect with the social aspect of human-human interactions. The world is already bombarded by the ubiquitous nature of social media and there is no shortage of games available for the Facebook social media platform. Dozens of companies have created games that can be played on numerous devices with the option of inviting friends on Facebook. Popular games such as Farmville and Candy Crush Saga allow for connecting to Facebook to ask friends for extra lives, boosts, virtual coins and other items to aid users along their quest. Without the ability to plug into social media and interact with others, many features are not available to the single user, thus eliminating the fun factor of interacting with other players.

Having the ability to connect to social media and see the achievements of others, ask peers for help and even interact with teachers would be a way of leveraging social interactions within the program. In addition, it may make the experience of using the program more entertaining, thus providing a more enhanced user experience and boost motivation resulting in an increase in learning.

What adults often see as fun is not necessarily the same type of fun that would appeal to students. Similarly, what developers consider to be good user experience does not coincide with an end user's definition of good design. When designing for other users, who generally constitute a different population than designers and developers, it is important to be mindful of ethnography. Conducting ethnographic studies to compile a profile, or profiles, of users and learners may be difficult and require extensive research. However, it would provide much insight and understanding into the lives of the target users and can afford valuable information in creating an experience that is positive, entertaining, engaging and free of frustration for a wide range of audiences.

The results from this study present new knowledge regarding personalized learning experiences in the secondary educational setting. Generally, the study suggests that personalized learning does not directly impact learning more than the non-personalized learning environment. This study does suggest that usability concerns may play a major factor in the learning experience. Further investigations of improving usability concerns in the personalized learning environment would be beneficial to address since having a better understanding of a technological tool's value is essential in supporting and creating significant learning experiences. In addition, the human and social element of interacting with technology could be further explored and compared to individualized use of technology.

Although personalized learning has been around in many forms for decades, it has not proven to be an effective replacement for a human instructor. Technology in education has not been shown to surpass instruction carried out by a human. Social interactions are very complex and we do not have the technology available to adequately imitate the relation and connections shared between humans. Complex thought processes, extrapolation of ideas and creativity are things that computers cannot accomplish in the same fashion as a human. While technology, such as the use of the web in asynchronous discussion boards to provide a means to represent a complete, social environment in order to support students' demonstration of higher-level critical thinking skills when provided with the appropriate guidance (Giacumo, 2012), is able to provide a means of having higher order levels of discussions taking place, this is made possible because of humans interacting with each other during the learning process. New tools that become available along with personalized learning environments should be used as a tool to supplement instruction and not altogether replace the human element of a teacher.

As personalized learning becomes more pervasive in education, researchers should continue to examine the relationship between the social aspect of learning and technology, the importance of sound usability principals in designing instructional content and the effect that these factors could have on student achievement and learning.

Conclusion

As personalized learning systems continue to evolve with technology and as research continues to identify ways in which maximum student achievement can be attained, it is important to note the social aspect of learning and how this is lacking in technology-based instruction. In addition, understanding the audience and its needs is the first step in developing a successful learning experience. Going a step further and understanding the individual needs of each learner in an audience is important in maximizing learning experiences. In order to understand individual needs, ethnographic surveying that researches who the audience is as a whole and each person individually is necessary. An understanding that the definition of entertainment is different across diverse age groups, ethnic backgrounds and other social nuances should be quintessential in the development of a product such as an educational tool or software.

After gaining an understanding of the audience, the creation of the product itself must be done so in accordance to a certain set of standards to ensure understanding across a wide range of audiences and pilot tested to ensure that the product is usable to a high degree. Creating products in accordance to a set of standards would involve developers and designers collaborating with teachers and educators in order to deliver a product that is appropriate for the wide range of students found in a classroom. In other words, although the problems themselves could be tailored to students, the overall content did not take into account that students did not relate to it. Using examples that are more relevant to the appropriate age group would motivate students to have a more positive perception of the product. In addition, working with educators is vital in developing a set of what Cohen et al. (1987) describe as a standard set of notations, symbols, units, nomenclature and styles that the program uses in order to match the representations used by the instructor to minimize confusion. Pilot testing of the product is also vital to eliminate as many bugs as possible. It is frustrating from a user's perspective to not be able to enjoy the experience of a product due to features not working properly, difficulty of interacting with the product and having software errors interfere with the overall experience.

The software used in the study is currently available on the desktop computer / laptop platform. Many schools are turning to more cost effective devices involving tablets (Fagen & Kamin, 2012; Hsu, Hwang, & Chang, 2013) and the ubiquitous mobile smartphones as a way of delivering instruction. If the software were to be ported to these devices, perhaps more schools and students would be inclined to adopt it. This would also make it easier for students to use the software anywhere without having to depend on being in front of a computer by affording them the ability to learn anywhere on the go. In addition, field testing (i.e. testing how students use the software at home or in a natural setting) versus lab testing (in a controlled environment) may play a role in how students score. Factors such as taking a study seriously, performing under the supervision of an adult versus on the go, self-regulation versus instructor-regulation and comfort or familiarity with the device in which the software is being used are other aspects that could be analyzed as factors affecting student performance.

Human emotion plays a role in learning (Gabriel & Griffiths, 2002) and prior studies have shown evidence that learners benefit greatly from cooperative learning experiences (D. W. Johnson, Johnson, & Smith, 1998; D. W. Johnson & Johnson, 2002; Martin, 2005). Additionally, students had higher level questions that required human response since that ability was beyond the scope of the program. The students sometimes turned to each other for questions when the instructor was not readily available. Allowing students to cooperatively work with the system may be beneficial in maximizing the experience of the social aspect of learning while using a program that has the personalization capabilities. A large part of the social aspect of learning and interaction involves connectivism (Siemens & Downes, 2008; Siemens, 2014) and people's use of social media - particularly students in the adolescent age group. Integrating social media into the program, or giving students the ability to connect to social media in order to interact with other students via the software may be beneficial in allowing questions to be asked, keeping track of personalized learning data the way social media platforms keep track of personal data, fostering a healthy environment of competitiveness and addressing the concern that the program is not entertaining enough.

Despite the aforementioned concerns, the results from the study did show that those who participated in the personalized learning condition did enjoy the personalized experience provided by the learning environment more than the overall experience it afforded. This could have resulted from the novel nature of the system and curiosity that accompanies trying out a new technology. While there is room for improvement, personalized learning environments still have the potential to reach a wide range of learners in an approach that takes into account each individual learner's need. Combining the suggestions mentioned can aid in developing a tool that can impact instructional effectiveness and student achievement by encouraging and supporting the collection of learner data as well as supporting educators in choosing tools that best suit them in delivering instruction while keeping their students' needs in mind.

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APPENDIX A

DEMOGRAPHICS SURVEY

Demographics Survey

Q	Question Text	Question Type	Answer Choices						
1	How old are you?	Short answer							
2	What is your grade level at school?	Short answer							
3	What math course or courses are you taking this semester?	Short answer							
4	Are you comfortable with using a laptop computer?	Yes/No	Yes	No					
5	Do you have access to a laptop computer and Internet at home?	Multiple choice [4 choices]	Yes, both laptop and Internet	Yes to a laptop, no to Internet	No to a laptop, yes to Internet	I don't have access to either at home			
6	What is your gender?	Multiple choice [3 choices]	Male	Female	Decline to answer				
7	Is English your primary language?	Yes/No	Yes	No					
8	How do you describe yourself? (please check the one option that best describes you)	Multiple choice [7 choices]	White / Caucasian	Hispanic or Latino	Black or African American	Native American or American Indian	Asian / Pacific Islander	Other	Decline to answer
9	How helpful are your family members with your math homework?	Rating [1-4]	1 = Very helpful	2	3	4 = Not helpful at all			

Note. *Q denotes question number.*

APPENDIX B

PRE-TEST AND CONTENT READINESS TEST

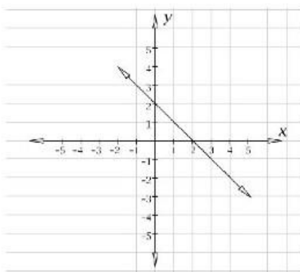
1. What is the simplified form of the following algebraic expression?

   $-8x + 5y + 11x - 4y$

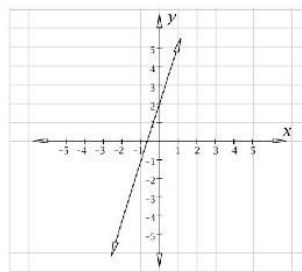
   A) $18x + 9y$ **B)** $-3x + 7y$ **C)** $13x + 15y$ **D)** $3x + y$

2. Which of the following is the graph of the linear equation $y = -3x + 2$?

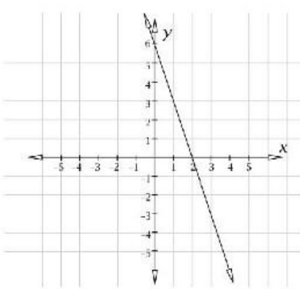
   A)



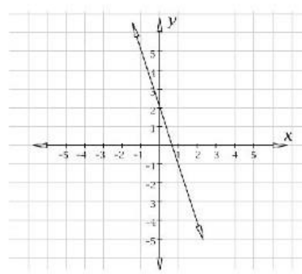
   B)



   C)



   D)



3. Translate the following problem into a one-step equation.

   Andrea is 175 centimeters tall. If she is 12 centimeters taller than Maria, then how tall is Maria? (Let Maria be m centimeters tall.)

   A) $m + 12 = 175$ **B)** $12 = m + 175$

   C) $m = 12 + 175$ **D)** $m = 12$

4. If $2n - 6 = 10$, then $n = ?$

A) 2 B) 4
C) 8 D) 16

5. Solve the following equation for x.

$3x + 7 = 5x - 2$

A) $\frac{9}{2}$ B) $\frac{-9}{2}$
C) $\frac{-5}{2}$ D) $\frac{5}{2}$

6. What is the solution of this absolute value equation: $|2x - 5| = 3$?

A) $x = 4$ and $x = 1$
B) $x = 4$
C) $x = 1$
D) The solution set is empty.

7. Solve the following system of equations:

$x - 4y = 3$
$3x + 2y = 9$

A) $x = 3$ and $y = 0$
B) $x = 5$ and $y = -3$
C) $x = 7$ and $y = 9$
D) $x = 11$ and $y = 1$

8. Factor the following expression.

$4x^3 + 4x^2 + 8x$

A) $x(4x^2 + 4x + 8)$ B) $4x(x^2 + x + 2)$
C) $4(x^3 + x^2 + 2x)$ D) $4x(x^3 + x^2 + 2x)$

9. Factor the following expression.

$9x^2 - 25$

A) $(3x + 1)(3x - 25)$
B) $(9x + 5)(x - 5)$
C) $(3x + 5)(3x + 5)$
D) $(3x + 5)(3x - 5)$

10. Factor the following expression.

$t^2 - 11t + 30$

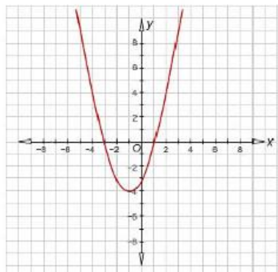
A) $(t - 5)(t - 6)$
B) $(t + 5)(t + 6)$
C) $(t + 5)(t - 6)$
D) $(t - 5)(t + 6)$

11. Complete the given table for $y = -2x^2 - 4x + 6$ and then determine the correct graph of it.

x	y
−3	0
−1	8
0	
1	0

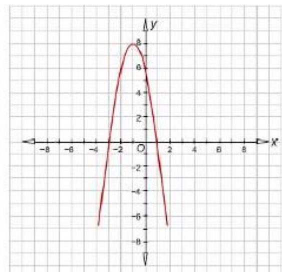
A)

x	y
−3	0
−1	8
0	−3
1	0



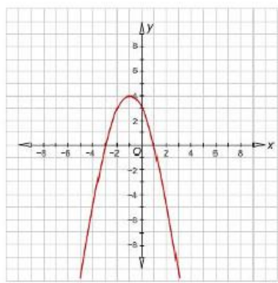
B)

x	y
−3	0
−1	8
0	6
1	0



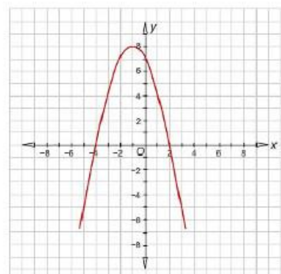
C)

x	y
−3	0
−1	8
0	3
1	0

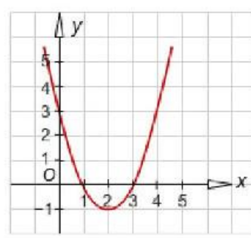


D)

x	y
−3	0
−1	8
0	3
1	0



12. The graph of the function $y = x^2 - 4x + 3$ is given. What is the range of this function when $0 \le x \le 4$?



A) $-1 \le y \le 5$

B) $-1 \le y \le 3$

C) $0 \le y \le 3$

D) $1 \le y \le 3$

13. Solve the following equation for x.

$x^2 - 4x - 21 = 0$

A) $x = 3,\ x = 7$
B) $x = -3,\ x = 7$
C) $x = 3,\ x = -7$
D) $x = -3,\ x = -7$

14. Solve the following equation for x.

$x^2 - 8x = 0$

A) $x = -8,\ x = 0$
B) $x = -4,\ x = 2$
C) $x = -6,\ x = 2$
D) $x = 8,\ x = 0$

15. What should the constant c be to make $x^2 + 10x + c$ a perfect square trinomial?

A) 5 **B)** 10
C) 25 **D)** 100

16. Solve the following equation for x.

$x^2 - 6x = 27$

A) $x = 9,\ x = -3$
B) $x = -9,\ x = -3$
C) $x = 9,\ x = 3$
D) $x = -9,\ x = 3$

17. Solve the following equation for x.

$2x^2 + 3x - 2 = 0$

A) $x = -3,\ x = \frac{1}{2}$ **B)** $x = 2,\ x = -\frac{1}{2}$
C) $x = -2$ **D)** $x = \frac{1}{2}$

18. Which of the following is the vertex of the parabola given by the quadratic function $f(x) = x^2 + 4x - 3$?

A) (2, 7) **B)** (−2, 7)
C) (2, −7) **D)** (−2, −7)

19. Which of the following models is most appropriate for the data set below?

(−2, 1), (0, −3), (1, −2), (3, 6)

A) Linear model
B) Quadratic model
C) Exponential model
D) None of the above

20. Which of the following shows the correct solution of the system of equations below?

$y = x^2 - 4x + 3$
$y = 3x - 3$

A) No solution **B)** (1, 0) only
C) (6, 15) only **D)** (1, 0) and (6, 15)

APPENDIX C

POST-TEST

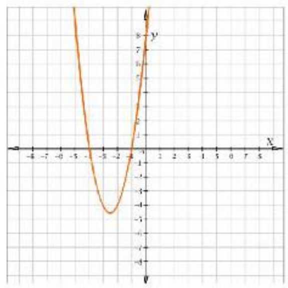
Student #:

1. Complete the given table for $y = -2x^2 - 10x - 8$ and then determine the correct graph of it.

x	y
0	
−1	0
−2	4
−3	4
−4	0

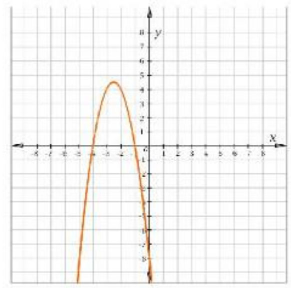
A)

x	y
0	8
−1	0
−2	4
−3	4
−4	0



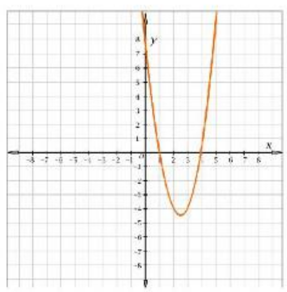
B)

x	y
0	−8
−1	0
−2	4
−3	4
−4	0



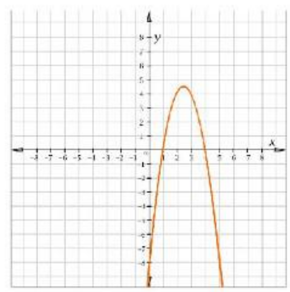
C)

x	y
0	8
−1	0
−2	4
−3	4
−4	0



D)

x	y
0	−8
−1	0
−2	4
−3	4
−4	0



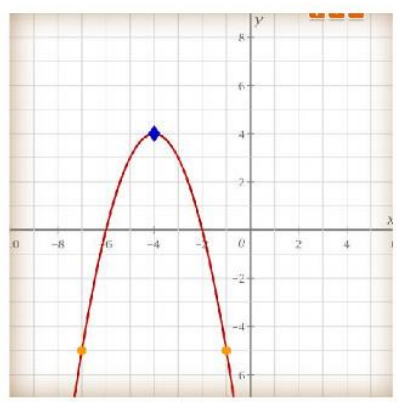
2. The graph of the function $y = -x^2 - 8x - 12$ is given. What is the range of this function when $-7 < x < -2$?

A) $-5 < y < 0$

B) $-5 < y \leq 4$

C) $-5 < y < 4$

D) $-5 \leq y < 4$



3. Solve the following equation for x.

$x^2 + 7x + 12 = 0$

A) $x = 3,\ x = 4$
B) $x = -3,\ x = -4$
C) $x = 7,\ x = 12$
D) $x = -7,\ x = -12$

4. Solve the following equation for x.

$2x^2 - 5x = 0$

A) $x = 0,\ x = \frac{-5}{2}$
B) $x = 0,\ x = \frac{5}{2}$
C) $x = 2,\ x = -5$
D) $x = 0,\ x = \frac{2}{5}$

5. What should the constant c be to make $x^2 - 8x + c$ a perfect square trinomial?

A) 8 B) 16
C) -16 D) 64

6. Solve the following equation for x.

$x^2 - 16x = 16$

A) $x = 8 - 4\sqrt{5},\ x = 8 + 4\sqrt{5}$
B) $x = 16 - 8\sqrt{5},\ x = 16 + 8\sqrt{5}$
C) $x = -1,\ x = 1$
D) $x = -16,\ x = 16$

7. Solve the following equation for x.

$3x^2 - 5x - 1 = 0$

A) $x = -2,\ x = 2$
B) $x = \frac{-5}{3},\ x = \frac{5}{3}$
C) $x = \frac{5-\sqrt{37}}{6},\ x = \frac{5+\sqrt{37}}{6}$
D) $x = \frac{5-\sqrt{37}}{3},\ x = \frac{5+\sqrt{37}}{3}$

8. Which of the following is the vertex of the parabola given by the quadratic function $f(x) = x^2 + 4x - 1$?

A) (-4, -1) B) (-2, -5)
C) (2, 11) D) (4, 31)

9. Which of the following models is most appropriate for the data set below?

(0, -2), (1, -6), (2, -18), (3, -54), (4, -162)

A) Linear model
B) Quadratic model
C) Exponential model
D) None of the above

10. What are the solutions of the system $y = -2x + 1$ and $y = x^2 - 2x - 3$?

A) (2, -3) and (-2, 5)
B) (1, -1) and (0, -3)
C) (-1, 3) and (1, -4)
D) (-2, 5) and (4, 5)

APPENDIX D

ATTITUDINAL SURVEY:

OVERALL EXPERIENCE SURVEY

Overall Experience Survey

Q	Question Text	Answer Choices			
1	I would like to use [redacted] during class.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree
2	I would like to be assigned [redacted] for homework.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree
3	Using [redacted] is a good use of my study time.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree
4	[redacted] gave me practice in topics I needed extra help with.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree
5	I would recommend [redacted] to a friend.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree
6	[redacted] flows logically from one video to the next.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree
7	[redacted] is personalized to my needs.	4 = Strongly agree	3 = Agree	2 = Disagree	1 = Strongly disagree

Note. *Q denotes question number.*

APPENDIX E

ATTITUDINAL SURVEY:

CONTENT EXPERIENCE SURVEY

Content Experience Survey

Q	Question Text	Answer Choices			
1	How engaging was the content you received?	4 = Very engaging	3 = Engaging	2 = Boring	1 = Very Boring
2	How helpful were the interactive modules in teaching the concepts?	4 = Very helpful	3 = Helpful	2 = Not so helpful	1 = Not helpful at all
3	Did you enjoy studying math with this program (compared to other math programs)?	1 = Not at all	2 = Not so much	3 = A little	4 = Very much
4	How often did you need to refer to the "How to Complete" information in order to complete an interactive module?	1 = Very often	3 = Often	3 = Very little	4 = Never

Note. *Q denotes question number.*

APPENDIX F

ATTITUDINAL SURVEY:

PERSONALIZED LEARNING EXPERIENCE SURVEY

(PERSONALIZED LEARNING CONDITION, ONLY)

Personalized Learning Experience Survey

Q	Question Text	Answer Choices			
1	Did the order in which the materials were given to you make sense?	1 = Not at all	2	3	4 = Just right
2	Did the program do a good job of recommending materials so that you had a chance to cover the topics you struggled with?	1 = Did a very good job	2	3	4 = Did poorly
3	Did the program do a good job of recommending materials so that you didn't spend too much time on the topics you did well on?	1 = Did a very good job	2	3	4 = Did poorly
4	Did the recommended items seem to be at an appropriate level of difficulty for you?	1 = Way too easy or way too hard	2	3	4 = Just right
5	Did the recommended items relate well to the goals of the assignment? Or, did you have to study some unnecessary concepts?	1 = Very well related	2	3	4 = Too much unnecessary content
6	How would you rate the overall quality of the order of materials you received in your assignments?	1 = Poor	2	3	4 = Great
7	Did you feel like the recommended items too scattered?	1 = Very scattered	2	3	4 = Well organized
8	How helpful was the "Achievement Forecast progress bar" in terms of showing your progress and work remaining?	1 = Very helpful	2	3	4 = Not helpful at all

Note. Q denotes question number.

APPENDIX G

OPEN-ENDED SURVEY QUESTIONS

Open Ended Survey Questions

Question Number	Question Text	Included in Non-Personalized Learning?
1	What did you like best about the platform? Please explain.	Yes
2	How do you think the system can be improved? Can you please name at least one useful feature to add?	Yes
3	What would you change about the platform?	Yes
4	Using three words, describe your experience with the platform.	Yes
5	How was the material personalized for you?	No*

Note.*This question only pertained to the Personalized Learning condition

APPENDIX H

IN LOCO PARENTIS

LETTER TO PRINCIPAL FROM DOCTORAL STUDENTS

Effect of Personalized Learning Paths on Learning Algebra

In Loco Parentis Letter of Permission

Dear Principal:

We are doctoral students conducting dissertation research on the topic of the Effect of Personalized Learning Paths on Learning Algebra under the direction of Dr. Gary Bitter, Professor of Educational Technology in the Division of Educational Leadership and Innovation at Arizona State University. This research will study the use of an online, adaptive, personalized platform with interactive multimedia content for training Algebra I students by exploring whether or not the system does a satisfactory job in providing teachers with quality student data in real time based on student performance using the adaptive personalized platform. The study also aims at analyzing the ease of using this data to inform instruction measure, aligning curriculum content to existing curriculum and measuring teacher satisfaction in terms of knowledge and understanding gained by students using the adaptive personalized platform.

We are inviting students in your school who are enrolled in Algebra I to participate in our research study, which will involve participating in and completing revised homework assignments in Algebra I that includes an online, adaptive, personalized platform with interactive multimedia content.

Student participation in this study is voluntary. If a student chooses not to participate or to withdraw from the study at any time, there will be no penalty. He or she will be able to complete the regular class requirements and receive a grade but his or her data will be removed from the study.

There are no foreseeable risks or discomforts to student participation. We will be collecting student work during the sessions. However, all of their work will be signed only with an anonymous study ID and therefore kept anonymous. All of the work collected will be kept in a locked cabinet or on a password-protected computer and will be destroyed after the end of the study. The results of this study may be used in reports, presentations, or publications but students' names will not be used.

If you have any questions concerning the research study or student participation in this study, please email Alpay Bicer at abicer@asu.edu or Caroline Savio-Ramos at casavio@asu.edu .

Sincerely,

______________________________ ______________________________

Alpay Bicer, Doctoral student Caroline Savio-Ramos, Doctoral student

---

By signing below, as principal of Hamilton High School you are giving consent *in loco parentis* for Hamilton High School students currently enrolled in Algebra I classes to participate in the above study.

______________________________ ______________________________

Printed Name Signature Date

If you have any questions about student rights as a participant in this research, or if you feel students have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788

APPENDIX I

IN LOCO PARENTIS

LETTER TO SCHOOL PRINCIPAL FROM PRINCIPAL INVESTIGATOR

Effect of Personalized Learning Paths on Learning Algebra

IN LOCO PARENTIS LETTER OF PERMISSION

Dear Principal:

I am a professor of Educational Technology in the Division of Educational Leadership and Innovation at Arizona State University. I am conducting a research study to investigate how students learn algebra concepts using an online, adaptive, personalized platform with interactive multimedia content.

I am inviting students in your school to participate in my research study, which will involve completing four homework assignments each of which will last approximately two-three hours. In these homework assignments, students will receive instruction on a mathematics concept. They will be asked to complete some exercises on this new material and judge the quality of some solutions. Student participation in this study is voluntary. If a student chooses not to participate or to withdraw from the study at any time, there will be no penalty.

Students and teachers will be provided incentives for participating. There are no foreseeable risks or discomforts to student participation.

I will be collecting student work during the sessions. However, all of their work will be signed only with a pseudonym and therefore kept confidential. All of the work collected will be kept in a locked cabinet or on a password-protected computer and will be destroyed one year after the end of the study. The results of this study may be used in reports, presentations, or publications but students' names will not be used.

If you have any questions concerning the research study or student participation in this study, please call me at (480) 965-4960 or email bitter@asu.edu .

Sincerely,

Dr. Gary Bitter

By signing below, as principal of ________________________________, you are giving consent *in loco parentis* for ____________________________________ students to participate in the above study.

____________________________ ____________________________ _________

Printed Name Signature Date

If you have any questions about student rights as a participant in this research, or if you feel students have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788

APPENDIX J

TEACHER RECRUITMENT LETTER

Recruitment Letter for teachers

Dear Teachers:

We are doctoral students conducting dissertation research on the topic of the Effect of Personalized Learning Paths on Learning Algebra under the direction of Dr. Gary Bitter, Professor of Educational Technology in the Division of Educational Leadership and Innovation at Arizona State University. This research will study the use of an online, adaptive, personalized platform with interactive multimedia content for training Algebra I students by exploring whether or not the system does a satisfactory job in providing teachers with quality student data in real time based on student performance using the adaptive personalized platform. The study also aims at analyzing the ease of using this data to inform instruction measure, aligning curriculum content to existing curriculum, and measuring teacher satisfaction in terms of knowledge and understanding gained by students using the adaptive personalized platform.

We are inviting you and your students who are enrolled in your mathematics courses to participate in our research study, which will involve student participation in and completing revised homework assignments in Algebra I that includes an online, adaptive, personalized platform with interactive multimedia content.

Both you and your students will be provided incentives for participating. The Algebra teacher helping us in coordinating will be provided a $300 gift card. The other participating teachers will be provided $100 gift cards, each. One hundred student names will be drawn in a lottery to receive $10 gift cards. In addition, the school will have one full year free subscription to the material (worth $50,000). There are no foreseeable risks or discomforts to student or teacher participation.

For the participating teachers, we ask no more than 1 hour per week of your time. For students, a homework assignment would follow with a 15-minute short discussion with the researcher. The discussions will be about how participants would describe the adaptive experience they have just had and what they like and do not like about the platform they have just used. The discussions will be recorded with an audio recording device for future analyses.

Your participation in this study is voluntary. If you choose to not participate or to withdraw from the study at any time, there will be no penalty or adverse action.

In addition, student participation in this study is also voluntary. If a student chooses not to participate or to withdraw from the study at any time, there will be no penalty. He or she will be able to complete the regular class requirements and receive a grade but his or her data will be removed from the study.

There are no foreseeable risks or discomforts to student participation, nor to you. Your name and information will be kept confidential. In addition, we will be collecting student work during the sessions. However, all of their work will be signed only with an anonymous study ID and therefore kept confidential. All of the work collected will be kept in a locked cabinet or on a password-protected computer and will be destroyed after the end of the study. The results of this study may be used in reports, presentations, or publications but students' names will not be used.

If you have any questions concerning the research study or student participation in this study, please email Alpay Bicer at abicer@asu.edu or Caroline Savio-Ramos at casavio@asu.edu. If you have any questions about student rights as a participant in this research, or if you feel students have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788

Sincerely,

Alpay Bicer and Caroline Savio-Ramos

Doctoral students

APPENDIX K

STUDENT RECRUITMENT LETTER

CHILD ASSEND FORM

Recruitment Letter for students (Child assent form)

Dear Students:

We are doctoral students conducting dissertation research on the topic of the Effect of Personalized Learning Paths on Learning Algebra under the direction of Dr. Gary Bitter, Professor of Educational Technology in the Division of Educational Leadership and Innovation at Arizona State University. This research will study the use of an online, adaptive, personalized platform with interactive multimedia content for training Algebra I students by exploring whether or not the system does a satisfactory job in providing teachers with quality student data in real time based on student performance using the adaptive personalized platform. The study also aims at analyzing the ease of using this data to inform instruction measure, aligning curriculum content to existing curriculum, and measuring teacher satisfaction in terms of knowledge and understanding gained by students using the adaptive personalized platform.

We are inviting you to participate in our research study, which will involve participating in and completing revised homework assignments in Algebra I that includes an online, adaptive, personalized platform with interactive multimedia content.

One of your homework assignments would follow with a 15-minute short discussion with the researcher. The discussion will be about how you would describe the adaptive experience you have just had and what you like and do not like about the platform you have just used. The discussion will be recorded with an audio recording device for future analyses.

We would like to audio record this interview. The interview will not be recorded without your permission. Please let me know if you do not want the interview to be recorded; you also can change your mind after the interview starts, just let us know.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. You will be able to complete the regular class requirements and receive a grade but your data will be removed from the study.

For full participation in our study, we are providing 100 students, randomly drawn in the form of a lottery, with an incentive of a $10 gift card at the conclusion of the study.

There are no foreseeable risks or discomforts to your participation. We will be collecting your work during the sessions. However, all of your work will be signed only with an anonymous study ID and therefore kept confidential. All of the work collected will be kept in a locked cabinet or on a password-protected computer and will be destroyed after the end of the study. The results of this study may be used in reports, presentations, or publications but your names will not be used

If you have any questions concerning the research study, please contact the research team at: Dr. Gary Bitter (bitter@asu.edu), Alpay Bicer (abicer@asu.edu), Caroline Savio-Ramos (casavio@asu.edu). If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

Sincerely,
Alpay Bicer, Doctoral student
Caroline Savio-Ramos, Doctoral student

(continued on the next page)

By signing below, you are giving consent to be interviewed, recorded, and participate in the above study.

__________________________ __________________________ ______

Printed Name Signature Date

If you have any questions about student rights as a participant in this research, or if you feel students have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788

APPENDIX L

LETTER OF SUPPORT FROM SCHOOL

April 15, 2015

Dear Institutional Review Board Chair and Members:

Please accept this letter of support for Alpay Bicer and Caroline Savio-Ramos. It is our intention at Hamilton High School to support Alpay and Caroline's research titled: "Effect of Personalized Learning Paths on Learning Algebra" and "The Role of an Adaptive System in Remediation and Knowledge Gains in Algebra: A Study of Personalized Learning as a First-Order Concern", described below.

Research Overview

Project Summary:

The goal of the first study is to investigate the effect of personalized learning paths which are continuously generated in real time by a true adaptive system and employs interactive multimedia content that can collect granular assessment data and provide granular recommendable units in Algebra. The study will compare this adaptive personalized platform with another platform that has exactly the same interactive multimedia content but presents them in a linear sequence. The "effect" will be investigated in terms of learning gains, learning efficiency, motivation, and satisfaction.

Objectives:

1. Explore whether or not the adaptive system is effective in delivering personalized learning as a tool for both learning and remediation in Algebra.
2. Exploring whether the system does a satisfactory job in providing instructors with quality student data in real time based on student performance.
3. Analyzing the ease of using this data to inform instruction measure, aligning curriculum content to existing curriculum, and measuring teacher satisfaction in terms of knowledge and understanding gained by students using the adaptive intelligent tutoring system platform.
4. Measuring the satisfaction of students using the system, receiving data, and understanding the content on the system – including ease of use of the system and content.
5. Improving modern educational curriculum and instruction in 21st century classrooms, helping educators choose adequate tools for teaching and delivering personalized learning experiences for each student using adaptive systems, and leveraging student knowledge of adaptive systems to help learners in grasping the course subject material.

Sincerely,

Dr. Fred DePrez, Principal

Ms. Dee Sillanpaa, Assistant Principal

APPENDIX M

INSTITUTIONAL REVIEW BOARD

APPROVAL LETTER

ASU Knowledge Enterprise Development

EXEMPTION GRANTED
Gary Bitter
Division of Educational Leadership and Innovation - Tempe
480/965-4960
bitter@asu.edu
Dear Gary Bitter:
On 4/16/2015 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	study 1) Effect of Personalized Learning Paths on Learning Algebra study 2) The Role of an Adaptive System in Remediation and Knowledge Gains in Algebra: A Study of Personalized Learning as a First-Order Concern
Investigator:	Gary Bitter
IRB ID:	STUDY00002510
Funding:	Name: Adaptive Curriculum
Grant Title:	
Grant ID:	
Documents Reviewed:	• Professor to Principal IN LOCO PARENTIS, Category: Consent Form; • Recruitment letter to high school students, Category: Recruitment Materials; • Caroline Savio-Ramos CITI Training, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Personalized Learning study - Funding Proposal.pdf, Category: Grant application; • Alpay Bicer dissertation proposal, Category: Other (to reflect anything not captured above); • Alpay Bicer CITI Training completion, Category: Non-ASU human subjects training (if taken within last 3 years to grandfather in); • Teacher Recruitment-Consent, Category: Consent Form; • Letter of support from Hamilton High School, Category: Consent Form; • Student to Principal IN LOCO PARENTIS, Category: Consent Form; • HRP-503a-PROTOCOL_SocialBehavioral_AC_STUDY.docx, Category: IRB Protocol; • Caroline Savio-Ramos dissertation proposal, Category: Other (to reflect anything not captured above);

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (1) Educational settings on 4/16/2015.
In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).
Sincerely,

IRB Administrator

BIOGRAPHICAL SKETCH

Caroline Savio-Ramos was born Caroline Savio in New Jersey. She completed her high school education at Ridgewood High School in Ridgewood, NJ and went on to Rutgers University in New Brunswick to obtain her B.A. in Physics and Spanish in 2001. In 2004, Caroline graduated with her M.A. in Science Education from New York University's Steinhardt School of Education and began her career as a high school physics teacher. While teaching, she completed her M.S. in Educational Technology from Ramapo College in 2010. Shortly after getting married in the spring of 2011, Caroline moved to Arizona to pursue her Ph.D in Educational Technology at Arizona State University where she defended her dissertation in October 2015. Upon finishing her doctorate degree, Caroline moved to the Silicon Valley where she began her career as a human factors engineer at Hewlett-Packard Enterprise.