Does Self-Regulated Learning-Skills Training Improve High-School Students' Self-Regulation, Math Achievement, and Motivation While Using an Intelligent Tutor?

by

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ABSTRACT

This study empirically evaluated the effectiveness of the instructional design, learning tools, and role of the teacher in three versions of a semester-long, high-school remedial Algebra I course to determine what impact self-regulated learning skills and learning pattern training have on students' self-regulation, math achievement, and motivation. The 1st version was a business-as-usual traditional classroom teaching mathematics with direct instruction. The 2rd version of the course provided students with self-paced, individualized Algebra instruction with a web-based, intelligent tutor. The 3rd version of the course coupled self-paced, individualized instruction on the web-based, intelligent Algebra tutor coupled with a series of e-learning modules on self-regulated learning knowledge and skills that were distributed throughout the semester.

A quasi-experimental, mixed methods evaluation design was used by assigning pre-registered, high-school remedial Algebra I class periods made up of an approximately equal number of students to one of the three study conditions or course versions: (a) the control course design, (b) web-based, intelligent tutor only course design, and (c) web-based, intelligent tutor + SRL e-learning modules course design. While no statistically significant differences on SRL skills, math achievement or motivation were found between the three conditions, effect-size estimates provide suggestive evidence that using the SRL e-learning modules based on ARCS motivation model (Keller, 2010) and Let Me Learn learning pattern instruction (Dawkins, Kottkamp, & Johnston, 2010) may help students regulate their learning and improve their study skills while using a web-based, intelligent Algebra tutor as evidenced by positive impacts on math achievement, motivation, and self-regulated learning skills.

The study also explored predictive analyses using multiple regression and found that predictive models based on independent variables aligned to student demographics, mastery learning skills, and ARCS motivational factors are helpful in defining how to further refine course design and design learning evaluations that measure achievement, motivation, and self-regulated learning in web-based learning environments, including intelligent tutoring systems.

DEDICATION

I dedicate this dissertation to my father, Kim Brown Barrus, who has modeled throughout his life the importance of hard work, achieving goals and using your talents to help other people learn how to be successful. I also dedicate this dissertation to my mother, Mary Beth Barrus, who is a life-long learner who seeks knowledge, understanding and wisdom from a wide variety of sources, people and experiences. She is always willing to listen to my ideas and offer her ideas in return. She is my favorite collaborator.

I also dedicate this dissertation to all four of my grandparents. They too have believed in me and taught me by example how to work consistently and with integrity toward my goals. They along with my parents have taught me to love God and His son Jesus Christ which has led me to peace, safety, happiness and a great love for learning and teaching. I am so grateful for all of the love and support I have received from these amazing people.

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INTRODUCTION

General Problem

Math and science learning, usually referred to as part of a STEM (Science, Technology, Engineering and Math) initiative being implemented at the state and national level, continues to be a focus area for educational reform with the express purpose of assisting students in preparing for and performing in 21st century jobs (NSF.gov, 2012). Improving STEM learning among U.S. students is a policy-driven, research-funded focus area for the White House and other government agencies. The 2013 Budget of the United States Fiscal Year 2013 calls for $260 million in funding for science, technology, engineering, and mathematics (STEM) programs. There is also a budget fund of $30 million specifically for evidence-based math education initiatives to be jointly administered with a comparable program at the National Science Foundation (White House.gov, 2013). STEM fields continue to be a strong focus of reform efforts, including developing common core standards across states, improving and strengthening curricula, promoting more advanced and specific course taking in the STEM arena, enhancing teacher quality, raising graduation requirements, and expanding technology use in education (NSF.gov, 2012).

Many high school students in Arizona struggle to learn and achieve in their math courses due to their lack of foundational skills upon completion of the 8th grade. In 2011, 69% of Arizona's 8th graders tested at below the proficient level in math and 32% tested at below the basic level in math (Nation's Report Card, 2011). The National Assessment of Educational Progress in Grades 4 and 8, also referred to as The Nation's Report Card, defines the basic level of math as exhibiting evidence of conceptual and procedural understanding with a level of performance that signifies an understanding of arithmetic operations while the proficient level is defined as at grade-level. This large number of students that have failed to grasp the basic level and foundational arithmetic operations of math required by the completion of 8th grade enter high school Algebra at a serious disadvantage to successfully achieve and progress appropriately through the four-year high school math learning model.

Research has been conducted to measure the proficiency levels of 9th grade students that are entering high school. One such example is the HSLS:09 study, a nationally representative longitudinal study of more than 21,000 9th graders in 944 school districts. HSLS:09 included an algebra assessment that provides indicators of 9th graders' proficiency in five specific algebraic skill areas (NSF.gov, 2012). These skill areas defined in the HSLS:09 are listed below. According to the HSLS:09 (NSF.gov, 2012), if a student is proficient in a higher level, he or she is also proficient in all lower levels.

1. Level 1, Algebraic expressions: Understands algebraic basics including evaluating simple algebraic expressions and translating between verbal and symbolic representations of expressions.
2. Level 2, Multiplicative and proportional thinking: Understands proportions and multiplicative situations and can solve proportional situation word problems, find the percent of a number, and identify equivalent algebraic expressions for multiplicative situations.
3. Level 3, Algebraic equivalents: Understands algebraic equivalents and can link equivalent tabular and symbolic representations of linear equations, identify equivalent lines, and find the sum of variable expressions.
4. Level 4, Systems of equations: Understands systems of linear equations and can solve such systems algebraically and graphically and characterize the lines (parallel, intersecting, collinear) represented by a system of linear equations.

5. Level 5, Linear functions: Understands linear functions and can find and use slopes and intercepts of lines and functional notation.

In 2009, the majority of 9th graders were proficient in lower level algebra skills, including 86% being proficient in algebraic expressions and 59% being proficient in multiplicative and proportional thinking. However, only 9% of 9th graders demonstrated proficiency in linear functions, the highest algebra skill level assessed by HSLS (NSF.gov, 2012).

Often these 8th and 9th grade students struggle with math learning and specifically moving beyond the most basic proficiency levels because the learning and practice strategies associated with learning math are different than other subjects (Nolting, 2002). Math course achievement requires students to remember and use material they have learned previously to be able to learn and practice new concepts (Nolting, 2002). Because the nature of the math learning process is different than many other courses' read, memorize, and reproduce methods of learning, it can be very frustrating to students and limit their motivation to persist. Often, students need personalization of the learning through one-on-one-tutoring to be able to work at their own pace and ask specific questions.

Another aspect of the math learning issue is related to the difficulty students often face in maintaining motivation and persistence along with other self-determination and self-regulation behaviors when new technology tools are introduced, including online learning environments, such as intelligent tutoring systems, that may appear to them to lack the structure and teacher scaffolds and support that they are more accustomed to (Azevedo & Cromley, 2004). The power of intelligent tutoring systems that offer the ability to more efficiently provide personalized learning can more fully be realized if students' frustration and ability to persist in practicing using these systems is better scaffolded and supported through self-regulation and motivation-based practice. The goal of this field-based dissertation study was to investigate the effectiveness of intervening in a high-school semester 1 math course for remedial Algebra students by delivering training on and distributed practice of self-regulated learning and math study strategies to improve the effectiveness of personalized practice using an off-the-shelf algebra intelligent tutoring system.

Intelligent Tutoring Systems

Intelligent tutors have been in development since the early 1970s and currently a host of commercial software companies and academic institutions are developing and providing web-based access to intelligent Algebra tutors (Woolf, 2009, VanLehn, 2011). The power of the Internet and continued advances in computer science continue to make it possible to provide personalized, computer-based tutoring in more efficient and inexpensive ways (Woolf, 2009). As research and development continues to innovate and evolve the features and capabilities of intelligent tutors, these tutors are showing in comparative evaluation studies to be equally if not at times more effective than human tutors. (VanLehn, 2011, Hannafin & Foshay, 2006).

Several distinctions differentiate intelligent tutors from other computer-based practice environments. First, the goal of intelligent tutors is to simulate and support teachers and well-regulated students rather than provide simply math fact drill and practice alone (Woolf, 2009). Also, equally importantly, intelligent math tutors leverage artificial intelligence to provide customized feedback and match the learning and practice needs of individual students. This includes focused practice on areas where a student is struggling, web-based links to help material, and problem-solving hints (Woolf, 2009, VanLehn, 2011).

Woolf (2009) proposed a theoretical framework for leveraging intelligent tutors to provide targeted learning and practice for Algebra students. It is built on the notion that we can create more effective knowledge-centered, web-based learning environments that take advantage of advances in artificial intelligence to develop environments that are "able to reason about domain knowledge, provide structure, prioritize content delivery, understand what students need to know, and design learning events aligned to outcomes" (Woolf, 2009, p. 39).

Recently several empirical independent evaluation studies have been conducted to measure the effectiveness of intelligent-tutor based math instruction and practice environments for improving math achievement (Barrus, Sabo, Joseph, & Atkinson, 2011; Beal, Arroyo, Cohen, & Woolf, 2010; Hannafin & Foshay, 2006; Walles, Arroyo, & Woolf, 2007). While each of these studies was able to effectively demonstrate math learning from pre-test to post-test in intelligent tutoring environments, with relatively large effect sizes, students were often still unable to pass the course where the intelligent tutoring practice occurred. This was often specifically the case with lower-proficiency students (Barrus et al., 2011; Hannafin & Foshay, 2006). Recent research has created a link between students' inability to regulate their learning in computer-based learning environments and the use of such environments to result in effective practice that transfers to ongoing content domain performance (Azevedo & Cromley, 2004). This has also been shown in a large scale evaluation conducted by Campuzano, Dynarski, Agodini and Rall (2009), where a computer-based instructional program, Larson Algebra I, was evaluated and compared with an intelligent tutoring system known as Cognitive Tutor Algebra I. The Larson program was implemented as supplemental practice to traditional instruction while the Cognitive Tutor Algebra I was used as replacement Algebra I curriculum. The students assigned to the Larson program logged into the computer-based supplemental practice program for an average of 313 minutes per year during a six-week instructional period. The students assigned to the Cognitive Tutor Algebra I intelligent tutor worked for an average of 2,149 minutes per year during a 24-week instructional period. There were no significant differences reported between the two groups. The average standardized test score for the treatment group, the students that used the intelligent Cognitive Algebra I Tutor, was 37.3% correct. In other words, even though students practiced for approximately 35 hours using an intelligent tutoring system, they still did not "pass" a standardized Algebra I test designed to measure Algebra I proficiency (Campuzano, Dynarski, Agodini, & Rall, 2009).

Self-Regulated Learning

One of the reasons students do not reach proficiency levels using intelligent tutors as curriculum replacement is that they struggle to make the learning transition from a highly structured, teacher-led classroom environment to an individualized learning environment. This transition requires them to take more responsibility and control over their learning as the teacher acts more as a facilitator. (Winters, Greene, & Costich, 2008). In the early 1980s, researchers began to explore academic self-regulation to more fully understand how students could be taught to master their learning processes and strategies to produce academic skills and outcomes (Zimmerman, 2001). In support of this definition, several cognitive models have been tested that define self-regulated learning as "an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior in the service of these goals" (Azevedo & Cromley, 2004, p. 523). There are several theoretical models that demonstrate a research basis for the contextual, cognitive and motivational aspects of learning, including self-efficacy, task definition, goal setting and planning, studying tactics, and adaptations to metacognition or thinking about learning (Azevedo & Cromley, 2004; Greene & Azevedo, 2007; Pintrich, 2000; Zimmerman, 2001). One of the most prevalent models focuses on evaluating self-regulated learning through an information processing lens with a focus on the memory's limited resources and the need to create schemas related to practice that allow students to automate academic skills (Winne, 2001).

Many researchers involved in the design, development, and evaluation of computer-based learning environments, including intelligent tutoring systems, have recently begun to explore in more depth how successful students self-regulate to fully take advantage of and achieve using computer-based learning environments, including intelligent tutoring systems. A meta-analysis of 369 research reports produced over the last 30 years related to self-regulated learning components and processes found a positive relationship between self-regulatory processes and learning, goal achievement, persistence, and self-efficacy (Sitzmann & Ely, 2011). A critical analysis reviewing 33 empirical studies tied the use of self-regulated learning in computer-based learning environments to the reality that students often struggle to use the tools and resources available in computer-based learning environments, including intelligent tutors, and have shown that students that employ self-regulated learning strategies achieve better and experience greater skill transfer. Additionally, these studies have shown evidence that adaptive scaffolding using an intelligent tutor and training students to use self-regulated processes and strategies before and while they use computer-based learning environments improves achievement (Winters, Greene, & Costich, 2008). This adaptive scaffolding supports students as they learn how to improve their problem solving skills and become better at self-determining how and what they need to practice to be prepared to perform well on course assessments (Kostons, Gog, & Paas, 2012).

Practice and Self-Regulated Learning

Practice is one of the fundamental skills of math learning. Math practice is engaged in using algorithms and formulas that are employed using step-by-step processes to reach accurate problem solutions (Nolting, 2002). Practice is also a life-skill that helps prepare students to more effectively self-regulate their learning (Lazakidou & Retalis, 2010, Goffin & Tull, 1985). As students learn to follow the process to most effectively solve math practice problems, they are also engaging in activities that help them gain “useful attitudes such as thinking, flexibility, creativity, and productivity which are very important to real life” (Lazakidou & Retalis, 2010, p. 3). These attitudes are also very important to each student’s ability to learn and use effective self-regulation practices that are self-determined (Kostons, Gog, & Paas, 2012).

Math course curricula can be designed and delivered to provide learners more control over the learning tasks since this is believed to improve self-regulatory learning skills (Hannafin, 1984) and provide a better context for “personalized learning trajectories” (Kostons et al., 2012, p. 121). Intelligent tutors are designed to provide personalized learning and practice plans based on a computer-based algorithm that determines what students need to practice and master to gain context-specific proficiencies (Azevedo & Jacobson, 2008).

There is power in personalized instruction and practice for targeting learner needs and helping the learning remain relevant and useful for each learner. Having all learners follow the same instruction or practice schedule, which is often designed to best assist the average learner, does not produce as effective of a learning experience as a more personalized approach that allows learners that struggle to receive additional support without getting lost and confused and learners that find new or review material easy to move forward without becoming bored (Kostons et al., 2012). It is difficult if not impossible in a traditional, teacher-led classroom to achieve personalized practice and learning for each student. It is much more practical to facilitate personalized learning and practice by designing course curricula that leverages computer-based, self-paced instruction including intelligent tutoring systems. (Woolf, 2009).

Scaffolding Problem Solving and Self-Regulated Learning

Self-regulated learning in computer-based learning environments, including intelligent tutoring systems, has been shown by researchers to be an effective way to support student learning and engagement (Azevedo & Cromley, 2004). However, scaffolding self-regulated learning while students learn in computer-based learning environments, including intelligent tutors, has been shown to be more effective than self-regulated learning training alone (Azevedo & Hadwin, 2005).

Some researchers assert that scaffolding involves providing assistance often to low prior-knowledge students and that scaffolds can be described as tools or strategies used during learning to help support student learning, practice, and retention (Azevedo & Hadwin, 2005). Scaffolding can support a range of instructional objectives and techniques in computer-based learning environments, including domain knowledge as well as thinking about and planning for learning in a particular context (Azevedo & Hadwin, 2005). Currently, there is limited empirical evidence to determine which type of scaffolds best support learning in computer-based learning environments, including intelligent tutoring systems (Azevedo, Cromley, & Seibert, 2004). This is due largely to the fact that the majority of research conducted regarding scaffolding in computer-based learning environments is “atheoretical and based on intuition regarding the design of hypermedia systems features… [and] many studies fail to adopt a theoretical framework to guide the research questions, to determine the types of data collection methods and corresponding analyses and to draw appropriate inferences” (Azevedo & Jacobson, 2008, p. 95). Several studies show that students who experienced significant gains from pre-test to post-test used effective strategies to regulate and plan their learning sub-goals and prior knowledge, which indicates that scaffolding learners who are not able to regulate in this way on their own may improve learning achievement (Azevedo & Cromley, 2004; Winters et al., 2008).

Distributed Practice of Self-Regulated Learning and Problem Solving

One method for scaffolding self-regulated learning and math practice strategy training to increase motivation is to use distributed instruction and practice of self-regulatory and problem-solving skills rather than teaching about self-regulation, including study strategies and problem-solving processes, in one massed instructional session. Some researchers have broadened the definition of what is usually referred to as distributed practice to include distributed sessions of instruction combined with practice by specifically pointing out that distributed practice and spacing research has been successfully applied in a variety of training, educational, and even athletic contexts (Benjamin & Tullis, 2010).

Distributed instruction and practice, also known in the literature as spacing or lag effect, is defined as "a memory advantage that occurs when people learn material on several separate occasions, instead of a single massed study episode" (Sobel, Cepeda, & Kapler, 2010, p. 763). The period of time associated with distributed instruction and practice schedules is known in the research as the inter-session interval. Several current studies have varied the inter-session instruction and practice interval to determine its effects on achievement and specifically retention (Cepeda, Pashler, Vul, Wixed, & Rohrer, 2006; Rohrer & Taylor, 2006). One of the simplest ways to understand and apply distributed instruction and practice theories is to evaluate the effects of reminding theory during learning episodes (Benjamin & Tullis, 2010). When a new learning episode and its associated tasks remind learners of a previous learning episode, the act of retrieving the information learned in the previous episode enhances memory and can increase skill (Benjamin & Tullis, 2010).

A meta-analysis completed in the late 90's showed that the retention benefits of distributed instruction and practice radically declined as the task became more conceptually difficult rather than simply a motor or recall skill (Donovan & Radosevich, 1999). However, in an attempt to hone in on increased practicality in the application of distributed instruction and practice, a math-specific study measured the benefits of spacing learning episodes involving instruction and practice problems across two sessions instead of massing those problems into one study session. Also, this study indicates that continued research is needed to compare groups of students who participate in instructional programs that use differing practice spacing techniques (Rohrer & Taylor, 2006). Finally, this study points out the power of using computer-based practice models based on algorithms to provide enhanced individualized instruction using distributed instruction and practice (Rohrer & Taylor, 2006).

Although nearly a century's worth of research has been conducted on the effects of distributed instruction and practice or spacing effect, including a meta-analysis published in 2006 that further substantiates the benefits of distributed instruction and practice, little has been done to measure results in real-world classroom contexts to determine the impact on motivation and achievement using inter-session intervals to vary instruction and reminding of self-regulated learning skills in combination with practicing math skills using an intelligent Algebra tutor (Cepeda, Pashler, Vul, Wixed, & Rohrer, 2006).

Scaffolding the students' experience by distributing instruction and practice of self-regulated learning (SRL) and math learning strategies using reminding theory in conjunction with intelligent tutor-based Algebra practice that includes hints and prompts to scaffold student learning will hypothetically provide a more supportive math course context for increasing motivation, participation, and achievement by focusing on maintaining attention, relevance, confidence, and satisfaction across the course experience (Keller, 2010).

Using Instructional Theory to Inform Design and Evaluation

This study was completed using a multidisciplinary, learning sciences approach to instructional design and evaluation by using multiple instructional theories as well as certain kinds of instructional methods to provide insight and understanding on certain kinds of learning processes (Reigeluth & Carr-Chellman, 2009). The purpose of employing several learning theories in the instructional design and evaluation approach is to create research that is capable of contributing to a new paradigm for K-12 instruction and specifically, a potentially new paradigm for remedial Algebra learning (Reigeluth & Carr-Chellman, 2009). The principle focus of the learning theories leveraged to design and evaluate the remedial Algebra curriculum are those that seek to explain learner-centered teachers and classrooms. They seek to define and describe a shift from teaching to learning including ways to personalize learning, engage and motivate students to put more effort into learning, build confidence in students so they will assume increasing responsibility for their own learning, and scaffold learning more effectively to allow students to better manage their learning processes and pace. Technology plays a central role along with a revised paradigm related to the role of the teacher in the classroom. (Reigeluth & Carr-Chellman, 2009). The learning and instructional theories leveraged in the design and delivery of each of the course versions were those that allowed us to use the principles and processes of four, multidisciplinary learning theories to focus on the learner experience, including learning processes, learning patterns, learning conditions and learning actions.

The first learning theory focused on learning processes is Albert Bandura's social cognitive theory (Reeve, Ryan, Deci, & Jang, 2008). Bandura felt that behaviorism did not offer complete explanations of human behavior because of its primary focus on external factors related to learning processes; he conducted a series of seminal studies aimed to understand more about the internal processes associated with learning, including the impact that modeling has on motivation toward learning. He also, "integrated motivational processes with self-regulation" (Schunk, Pintrich, & Meece, 2002, p. 123). A learning process that leverages Bandura's theory is called observational learning where a teacher demonstrates a problem-solving process and associated tools that will help the student successfully solve the problem. The teacher then allows the students opportunity to practice based on what they have observed (Schunk et al., 2002).

Another aspect of social cognitive theory deals with the three processes that make up self-regulation: self-observation and monitoring, which requires a student to pay specific and deliberate attention to his or her behavior; self-judgment, which refers to the student comparing his current performance level with a goal performance level; and self-reaction, which refers to appraisals made by the student on the satisfactory nature of progress toward a goal (Schunk et al., 2002). Social cognitive theory is the basis for the need for and ability to teach students self-regulated learning skills and learning strategies to improve learning processes (Zimmerman, 2001).

The second learning theory focused on learning patterns is a recently research-based, validated learning process called Let Me Learn® (Johnston, 2010). Let Me Learn® (Johnston, 2010) was created to teach students to understand and leverage their preferred learning patterns and the strategies aligned to those patterns to self-determine and self-regulate their success by self-diagnosing and choosing to take actions that can reduce frustration during learning and practice (Johnston, 2010). Let Me Learn® (Johnston, 2010) defines its curriculum and process as an advanced learning system that leverages metacognitive skills and processes to improve thinking about learning by using self-talk to identify patterns and strategies for learning motivation and achievement (Johnston, 2010). The Let Me Learn® (Johnston, 2010) curriculum defines four foundational learning patterns known as Sequence, Precision, Technical Reasoning, and Confluence and instructs learners how to identify who they are, how they learn, and how to self-monitor and regulate their learning achievement in a variety of learning contexts by completing the Learning Connections Inventory® (Johnston, 2010). Learners that understand their patterns and how to adapt to a variety of learning situations are best positioned to self-determine and self-regulate their motivation and achievement (Johnston, 2010).

The third learning theory focuses more specifically on how motivation impacts self-regulation and learning. Motivation is a broad concept that is often employed in learning research, specifically intrinsic motivation, which is defined as a shift from the behaviorist views of external reinforcement to the self-determination and self-regulation of actions (Brophy, 2010). The motivation model intended to be used in conjunction with proven instructional design models was introduced by Keller (1979) to specifically address the issue of increasing motivation and self-determination in terms of four student-focused learning conditions, namely, attention, relevance, confidence, and satisfaction (ARCS) (Cheng & Yeh, 2009).

The fourth learning theory known as self-determination is a specific theory dedicated to studying intrinsic motivation. According to Brophy (2010), the concept of self-determination is defined as a context where autonomy, competence, and relatedness are supported to allow students to choose their own success. Online learning environments require increased levels of intrinsic motivation and specifically self-determination for optimal levels of achievement and retention to occur (Cavanaugh & Blomeyer, 2007).

As the world continues to change through the implementation of new technologies, learners must have insight into their learning processes, learning patterns, learning conditions, and learning actions to help them continue to personally and professionally persevere in their life-long learning and development opportunities, including the four years of required math at the high-school level. Self-regulated learning and self-determination are skills that can be taught by helping students to become more aware by reflecting on their behavior, motivation, and cognition (Pintrich, 1995). It is important to not only instruct students to provide knowledge and "how-tos" related to skill development but to also include instruction about self-monitoring, which can be summarized as obtaining relevant information using perception and metacognition or thinking about learning to inform self-regulatory decisions (Pintrich, 1995).

The Let Me Learn® curriculum based on the learning theory (Johnston, 2010), Winning at Math (Nolting, 2002), and the ARCS Motivation Model (Keller, 2010) served as reference and framework documents in the design and development of a set of 19 web-based, self-regulated learning and math learning strategy e-learning modules used to instruct and provide students with practice on self-regulation principles, processes, and skills. These modules were designed by employing two proven instructional design models to create a theoretical design and development base for the structure and content, supported by Keller's ARCS motivation model, including Gagne's Events of Instruction and Dick and Carey's Systematic Design of Instruction that employs the

ADDIE model (Dick, Carey, & Carey, 2009; Keller, 2010; Reigeluth & Carr-Chellman, 2009).

OVERVIEW OF STUDY

Purpose

This study was run in the field using a high-school Algebra course as a partnership between the researcher and the course instructor. The main benefit of running a field-based course evaluation study was the ability to collect empirical evidence of student performance in the day-to-day high school setting where the department chair and other Algebra instructors wanted to determine if course design changes would be beneficial.

The purpose of the study was to determine the impact of each version of the Algebra I remediation course on self-regulated learning skills, math achievement, and motivation among high-school students who had failed to pass Algebra I previously. All three versions of the course used a consistent Algebra I curriculum aligned to the Arizona State Math Standards and were designed by one instructional designer in partnership with one high-school Algebra teacher. This same high-school Algebra teacher delivered all three versions of the remedial Algebra I course during three different class periods throughout each school day of the entire Fall 2012 semester.

The math department chair and the school district have invested in technology tools, including intelligent Algebra tutors, to improve Algebra learning and help students pass the four years of math required to graduate high school. Leadership in the district as well as at the high school expressed an interest in evaluating different course designs to determine how to most effectively instruct and evaluate remedial Algebra students using technology by measuring the impact that different technology-enhanced course designs had on student achievement, self-regulated learning, and motivation. Because the intelligent tutors have shown to be effective for learning in other remedial Algebra settings (Barrus et al., 2011), this study included the instructional design of three different versions of a remedial, technology-enhanced Algebra course and compared them using a field-study approach to experimental design. The course designs were evaluated to determine their impact on student achievement, motivation, and self-regulation. The goal of designing and comparing multiple versions of the course was to inform the Mesa High School department chair to consider policy changes that would revise the course design for ongoing remedial Algebra courses at Mesa High School and potentially other high schools in the Mesa School District.

Importance

This study was intended to inform math teachers, administrators, and evaluation researchers how to optimally implement and scaffold technology, including intelligent tutors as personalized practice environments, into math course curriculum. It was also designed to assist instructional designers and developers by providing empirical evidence for updating technology-enhanced course designs to include self-regulated learning, self-determination and math study strategy distributed instruction, and practice in courses that leverage online learning environments such as intelligent tutors.

Conditions

A quasi-experimental evaluation design was used by assigning intact, pre-registered, high-school remedial Algebra I class periods made up of approximately 25 students per class to one of the three study conditions or course versions: a) the control course design, (b) web-based, intelligent tutor only course design, and (c) web-based, intelligent tutor + SRL e-learning modules course design.

Research Questions

1. Does self-regulated learning instruction provided in conjunction with web-based, intelligent practice increase students' self-regulated learning skills, math achievement, and motivation more than the intelligent, web-based practice alone, controlling for prior Algebra knowledge, motivation, and self-regulated learning skills?
2. Does an intelligent algebra tutor increase math achievement over classroom instruction (i.e., the business-as-usual control course design) controlling for prior Algebra knowledge?
3. To what extent are student descriptives, SRL skills, learning patterns, motivation, persistence, work effort, and the ARCS materials survey results predictive of changes in SRL skills, math learning achievement, and motivation after participating in a remedial Algebra course?

Hypotheses. Based on the study conditions, the following hypotheses will be investigated:

Primary Hypotheses. Students who participated in a course that provides the SRL e-learning modules plus intelligent web-based practice will achieve higher math scores, be more motivated, and increase in their SRL skills better than the intelligent web-based practice only version of the course. H1: SRL E-Learning Modules Course Version > Web-based, intelligent tutor only course design.

Students who participated in a course that provides SRL e-learning modules plus intelligent web-based practice will achieve higher math scores, be more motivated and increase in their SRL skills better than the control version of the course. H2: SRL e-Learning Modules course design > control course design.

Covariates

1. SRL Motivation Pre-Test
2. Acuity Algebra Pre-Test
3. SRL Information Processing Pre-Test

En Route Variables

1. Attendance in class (Persistence)
2. Sections completed in web-based, intelligent Algebra tutor (Work Effort)

Dependent Variables

1. SRL Knowledge/Skills Post-Tests
    1.1. Attitude
    1.2. Information Processing
2. Learning Achievement: ACUITY Standardized Algebra I Assessment

Motivation: Post-Course LASSI Motivation Measure

Chapter 2

METHOD

Participants and Design

The participants in this study were comprised of three class periods of remedial Algebra students that included a total of approximately 74 high-school remedial Algebra students (approximately 25 per condition). There were 42 male and 32 female participants. 27 spoke English as their first language at home and 36 spoke Spanish as their first language at home, 1 spoke another foreign language as their first language at home. The average age of the participants was 15.7 years.

All participants had failed Algebra at least once previously at the high-school level. Many of the participants had truancy or other behavioral issues that cause them to miss class or to lose their computer privileges. Due to this challenge of conducting research in the field, this study experienced up to a 50% attrition rate across all three conditions on all three dependent measures. The attrition rate varied on the dependent measures because the measures were administered on different days. Table 1 below illustrates the attrition rates by study condition and dependent measure.

Table 1

Attrition Rates by Condition and Dependent Measure

Study Condition	Dependent Measure	Starting Size	Ending Size	Attrition Rate
Control Course Design	Achievement SRL/Motivation	25 25	15 12	40% 50%
Web-Based, Intelligent Tutor Only Course Design	Achievement SRL/Motivation	24 24	12 20	50% 20%
Web-Based, Intelligent Tutor + SRL e-Learning Modules Course Design	Achievement SRL/Motivation	25 25	12 12	50% 50%

The study design was a pre-test/post-test control-group design that compared two versions of the course design that used intelligent tutoring systems to a control course design condition as illustrated in the following table. A quasi-experimental design was used because students were previously assigned in preconfigured course sections making random assignment into study conditions not possible in this field setting. Refer to Table 2 below for a detailed description of the study design methods by study condition.

Table 2

Overview of Study Design by Study Condition

Study Condition and Description	Study Design

Control Course Design
 	
• Majority of students demonstrated interest/were on task
• Classroom generally orderly, but some disruptions impaired learning environment
• Effective help-seeking by students
• Students demonstrated effective critical thinking and persistence in learning.
• Aligned best to Attention in the ARCS model
• Students most concerned with Relevance and Satisfaction in the ARCS model
	• SRL and Algebra pre-tests
	  ○ Learning Connections Inventory (LCI)
	  ○ LASSI High School SRL Inventory Pre-Test
	  ○ Acuity Algebra Pre-Test
	• Three classroom observations
	• SRL and Algebra post-tests
	  ○ LASSI High School SRL Inventory Post-Test
	  ○ Post-tutorial ARCS attitude/motivation survey
	  ○ Acuity Algebra Post-Test

Web-Based, Intelligent Tutor Only Course Design
 	
• Majority of students demonstrated interest/were on task
• Classroom generally orderly, but some to more frequent disruptions impaired learning environment
• Effective help-seeking by most students
• Aligned best to Attention in the ARCS model
• Students most concerned with Confidence and Satisfaction in the ARCS model
	• SRL and Algebra pre-tests
	  ○ Learning Connections Inventory (LCI)
	  ○ LASSI HS SRL Inventory Pre-Test
	  ○ Inventory of Classroom Style and Skills
	  ○ Acuity Algebra Pre-Test
	• At least 40 hours of practice and test preparation in the ALEKS intelligent tutoring system.
	• Three classroom observations
	• SRL and Algebra post-tests
	  ○ LASSI High School SRL Inventory Post-Test
	  ○ Post-tutorial ARCS attitude/motivation survey
	  ○ Acuity Algebra Post-Test

Web-Based, Intelligent Tutor +SRL e-Learning modules
 	
Course Design
 	
• Majority of students demonstrated interest/were on task
• Classroom generally orderly, but some to more frequent disruptions impaired learning environment
• Effective help-seeking by most students
• Aligned best to Relevance in the ARCS model
• Students most concerned with Confidence and Satisfaction in the ARCS model
	• SRL and Algebra pre-tests
	  ○ Learning Connections Inventory (LCI)
	  ○ LASSI High School SRL Inventory Pre-Test
	  ○ Acuity Algebra Pre-Test
	• SRL Modules 1 per week for 12 Weeks during Fall 2012. (20 minutes of the 50-min class period each day.)
	• ALEKS intelligent tutoring system practice (30 minutes of the 50-min class period each day.)
	• Three classroom observations
	• SRL and Algebra post-tests
	  ○ LASSI High School SRL Inventory Post-Test
	  ○ Post-tutorial ARCS attitude/motivation survey
	  ○ Acuity Algebra Post-Test

Each version of the course was designated as a condition in the study. Each version of the course leveraged the ADDIE model of instructional design as well as the ARCS motivational course design model (Dick et al., 2009, Keller, 2010). Table 3 below details the instructional design distinctions based on the learning theory, instructional methods/ SRL methods, motivation methods, the role of the teacher and the role of technology in each version of the course.

Table 3

Study Condition Instructional Design Summary

Condition	Educational Theories	Instructional/ SRL Methods	Motivation Methods	Teacher Role	Tech Role
Control Course Design	• Social Cognitive Theory (Zimmerman, 2001) • ARCS Motivation Model (Keller, 2010)	• Direct instruction using modeling • Teacher feedback • Teacher directed time-on-task	• Attention • Confidence	• Lecturer • Demonstrator	• Presentation
Intelligent, Web-Based Practice Only Course Design	• Self-Determination Theory (Deci, 1996) • ARCS Motivation Model (Keller, 2010)	• Web-based, interactive modules • Self-paced instruction • Personalized instruction • Guided practice • Student directed time-on-task	• Attention • Confidence	• Facilitator	• Practice • Feedback
Web-Based, Intelligent Tutor +SRL e-Learning modules Course Design	• Social Cognitive Theory • Self-Determination Theory (Deci, 1996) • Let Me Learn (Johnston, 2010) • ARCS Motivation Model (Keller, 2010)	• Web-based, interactive modules • Self-paced instruction • Personalized instruction • Guided practice • Peer tutoring • Class discussion • Modeling • Learning patterns • Self-observation • Self-judgment • Self-reaction • Student directed time-on-task	• Attention • Relevance • Confidence • Satisfaction	• Facilitator • Coach	• Instruction • Practice • Feedback

Using the Let Me Learn® preferred learning pattern assessment and ongoing learning patterns curriculum along with the Winning at Math curriculum that provides specific strategies for successfully learning math in an online learning environment (Johnston, 2010, Nolting, 2002), I developed 19 web-based, self-regulated learning e-learning modules to provide students with insights about how they engage specific learning patterns and strategies to effectively overcome math learning frustration and increase motivation and achievement. The e-learning modules were developed using a social networking approach to design and interaction including features familiar in several popular social networking websites. The development platform used was SurveyGizmo, which allows item-by-item interaction while capturing log files of the students' behaviors and responses within the system. This initial release of the e-learning modules was designed to force students to complete every item, on every page in an attempt to focus students and help them have meaningful interactions with the content. This design decision was an attempt to control for work effort within the SRL e-learning modules.

The basic reporting features of the SurveyGizmo system report log data in the form of modules completed with 0% as not completed and 100% as completed. If the modules are marked as 100% completed, the student did interact with each piece of content within the module, however, it is difficult to understand how meaningful their interaction was with the content with the current back-end reporting tool. Also, students were allowed to repeat modules and review content but the system reporting tools do not currently capture if students chose to return and review certain segments of content. Since the basic reporting features included in SurveyGizmo were designed to provide survey results data the quantitative data provided by the system is not useful in understanding work effort, learning engagement or self-regulated learning skills mastery in a meaningful way. The reporting tool did allow us to determine that 18 of the 19 modules were completed. There is one module that is not showing completion data which could be due to students selecting to skip that module or a reporting error within the system. This completion measure is comparable to the work effort completed within the ALEKS intelligent tutoring system. Student comments were captured and can be exported, however, a reporting tool to provide summary data related to student comments and a qualitative coding system to analyze these comments is planned for the next iteration of the system. In this present version of the e-learning modules the content was leveraged more like a web-based, interactive textbook that currently lacks the ability to measure mastery learning. The purpose of this initial set of e-learning modules was to determine if self-regulated learning instruction and practice provide enough impact on self-regulated learning skills, motivation and achievement to warrant further investment into enhancing the system's feature set and functionality.

Specific SRL-related topics such as goal setting, persistence, time management, test-taking skills, listening, and note-taking skills were included. Also, reading and practice techniques for taking control and learning math using an intelligent tutor were integrated into the web-based, instructional modules. Table 8 below details the instructional design process used to instructionally design the web-based, self-regulated learning modules for the SRL Tutorial + intelligent tutoring course design and the screen shots show how the student experienced an SRL module.

SRL E-Learning Modules Instructional Design Overview

Design Summary

- 19, mini-modules that can be completed in approximately twenty minutes each.
- Each mini-modules is broken up into three learning experiences including:
    a. Learn About It
    b. Talk About It
    c. Share About It
- Attitude survey (Pre/Post)
- LCI Learning Pattern Assessment (Pre Only; Johnston, 2010)
- ARCS Instructional Materials Motivation Survey (Post Only, Keller, 2010)

Module Objectives

1. Complete your learning profile.

2. Identify your learning patterns.
3. Associate your thoughts, attitudes and behaviors about math with your learning patterns.
4. Consider your help-seeking strategies.
5. Recognize your math learning strengths by leveraging your learning patterns.
6. Analyze your current in-class tutor-based practice and homework methods.
7. Prepare an effective study and practice plan for in-class and homework assignments.
8. Create tutor-based practice goals related to time management, feature help-seeking and self-monitoring.
9. Apply your learning patterns to improve your test-taking skills.
10. Evaluate and reward your willingness and ability to persist using your learning patterns.
11. Visualize your goals
12. Redefine how you view failure as it relates to your learning pattern and process.

Module Design Process (Gagne, ADDIE and ARCS)

Analysis

- Evaluate AIMS, GPA and other Mesa High school trend data for high school Algebra students who have failed to determine curriculum and SRL practice alignment.
- Interview Mesa High School math department chair to understand 3-5 potential student personas.
- Define instructional goals and strategies.

Design

- Refine course objectives and module topics based on audience analysis results.
- Include attention activities at the beginning of each class period and again at the beginning of each module to focus learners and reinforce SRL principles and practices.
- Align topics, principles and activities to the intelligent tutoring practice environment and success in Algebra to increase relevance for students.
- Create confidence-building, interactive activities that teach learners to think about their learning patterns and practices in positive ways.
- Teach students to apply self-monitoring to reinforce the real-world relevance and their satisfaction as they successfully persist in achieving their practice goals.
- Provide feedback and reinforcement within the module and through the teacher's methods for providing help.

Development

- Leverage emerging technologies and tools familiar to students to engage students and involve them in the learning environment.

- Use branching technology to allow users to make choices and exercise self-determination during the learning process.

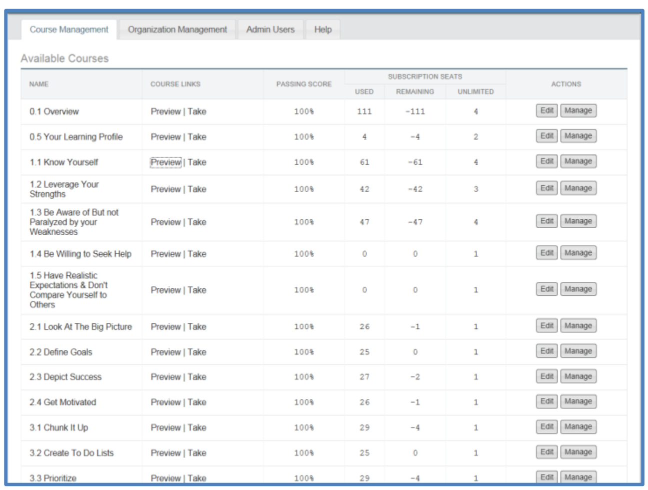
Implementation

- Train the math instructor to implement the training efficiently and effectively and reinforce the content when students seek help.

Evaluation

- Use log data as well as survey instruments aligned to Level 1 and 2 of the Kirkpatrick evaluation model in future study iterations (Russ-Eft & Preskill, 2009, p. 74-77) to determine level of SRL skill mastery and impact on attitudes.

Upon initial login each day, students select a module they would like to work on. In the first week of the course, the teacher guided students to complete the Overview and Your Learning Profile mini-modules in preparation for completing the remainder of the modules. Below in Figure 1 is a screen shot of the module list students saw each day when they logged in to begin work on the SRL portion of the course in the SRL Tutorial + ALEKS condition.



NAME	COURSE LINKS	PASSING SCORE	SUBSCRIPTION SEATS USED	SUBSCRIPTION SEATS REMAINING	SUBSCRIPTION SEATS UNLIMITED	ACTIONS
0.1 Overview	Preview | Take	100%	111	-111	4	Edit Manage
0.5 Your Learning Profile	Preview | Take	100%	4	-4	2	Edit Manage
1.1 Know Yourself	Preview | Take	100%	61	-61	4	Edit Manage
1.2 Leverage Your Strengths	Preview | Take	100%	42	-42	3	Edit Manage
1.3 Be Aware of But not Paralyzed by your Weaknesses	Preview | Take	100%	47	-47	4	Edit Manage
1.4 Be Willing to Seek Help	Preview | Take	100%	0	0	1	Edit Manage
1.5 Have Realistic Expectations & Don't Compare Yourself to Others	Preview | Take	100%	0	0	1	Edit Manage
2.1 Look At The Big Picture	Preview | Take	100%	26	-1	1	Edit Manage
2.2 Define Goals	Preview | Take	100%	25	0	1	Edit Manage
2.3 Depict Success	Preview | Take	100%	27	-2	1	Edit Manage
2.4 Get Motivated	Preview | Take	100%	26	-1	1	Edit Manage
3.1 Chunk It Up	Preview | Take	100%	29	-4	1	Edit Manage
3.2 Create To Do Lists	Preview | Take	100%	25	0	1	Edit Manage
3.3 Prioritize	Preview | Take	100%	29	-4	1	Edit Manage

Figure 1: SRL module menu

Students then chose "Take" to enter the module they had decided to work on for 20 minutes that day. The first screen they encountered is the "Learn about it" section that displayed the content for the module selected and required the student to interact with each content element. Each time the student interacted with the content, a new piece of content was delivered.

Figure 2: Learn about it

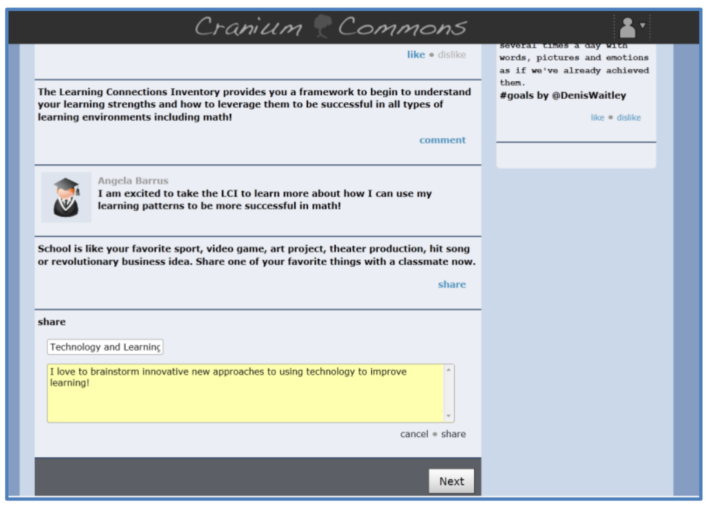


Figure 3: Like, dislike, comment content interactions

Upon completing the “Learn about it” section, the student clicked “Next” and was brought to the “Talk about it” page. This section presented content in a simulated classroom experience where an experienced math teacher provided self-regulated learning in the math classroom instruction and simulated, peer students joined in a classroom discussion. The student participating in the module “listened-in” on and interacted with the classroom discussion by again liking, disliking, and commenting throughout the conversation. The student were able to select the teacher or one of the peer students on the left to view his or her learning profile, including a summary of his or her learning patterns.

Figure 4: Talk about it

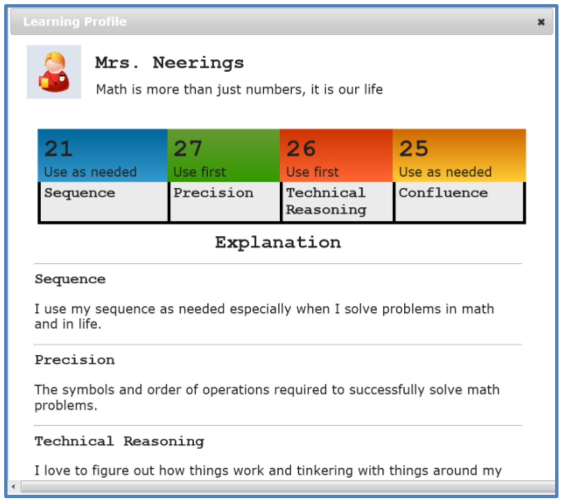


Figure 5: Simulated teacher learning profile

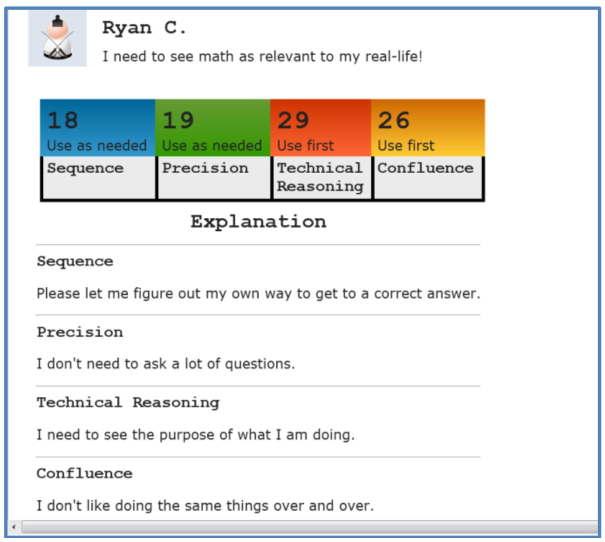


Figure 6: Simulated peer student learning profile

In both the “Learn about it” and “Talk about it” sections of each mini-module, the student reads quotes that are presented on the right-side of the screen to look like tweets. They are intended to help students be introspective and feel encouraged that they can improve their self-regulated learning skills.

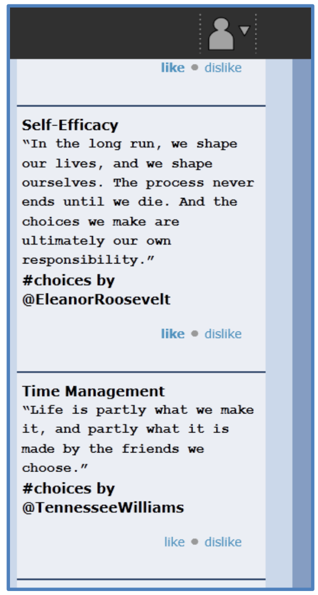


Figure 7: Simulated "tweets" of SRL quotes

Upon completing the "Talk about it" section, the student clicks "Next" and is brought to the "Share about it" page. This section presents a content summary on the left side of the page and challenges students to share or teach what they have learned in the mini-module with a parent, teacher, or friend. The final activity of the module then challenges the student to set a goal related to the module topic and math learning and to share that goal with others to help keep the student accountable.

Figure 8: Share about it and goal setting

Intelligent Algebra Tutor

An intelligent tutoring system designed to remediate math, the ALEKS pre-algebra product was selected based on usability feedback from students and teachers in previous studies as the intelligent tutoring practice environment. ALEKS's pre-algebra and algebra product are part of a web-based, artificially intelligent assessment and learning system that was customized to deliver instruction that aligns with Arizona State math standards. The pre-Algebra product provided standards-based coverage of all of Grade 8 Math, including a robust introduction to the basic concepts of Algebra and its prerequisites. The Algebra product provided standards-based coverage of Algebra 1 and prerequisites, but did not provide extensive coverage of non-Algebra mathematics topics, such as probability, statistics, and geometry. The curriculum for this course was aligned to the Mesa High School Algebra I final exam to adequately prepare students through their practice using the intelligent tutoring system to pass the final course assessment.

ALEKS used adaptive instruction and questioning to determine student knowledge. ALEKS then made topics available for students to select and instructed the students on the topics they were most ready to learn. As each student worked through the course, ALEKS reassessed each student regularly to ensure that new topics were introduced at the appropriate time and that foundational topics being learned were retained. The ALEKS system provided ongoing assessment to lead students to topic mastery and included help features intended to allow students to choose to be successful when interacting with the system and learning the algebraic concepts. Below is an overview of the ALEKS intelligent tutoring system with accompanying screen shots to illustrate the process the students experienced (ALEKS).

Upon initial login, students completed a pre-test to allow the system to customize a study plan for them as individuals. Figure 9 shows a sample pre-test question where students can indicate the answer or let the system know they do not feel comfortable answering the question because they have not learned the concept yet.

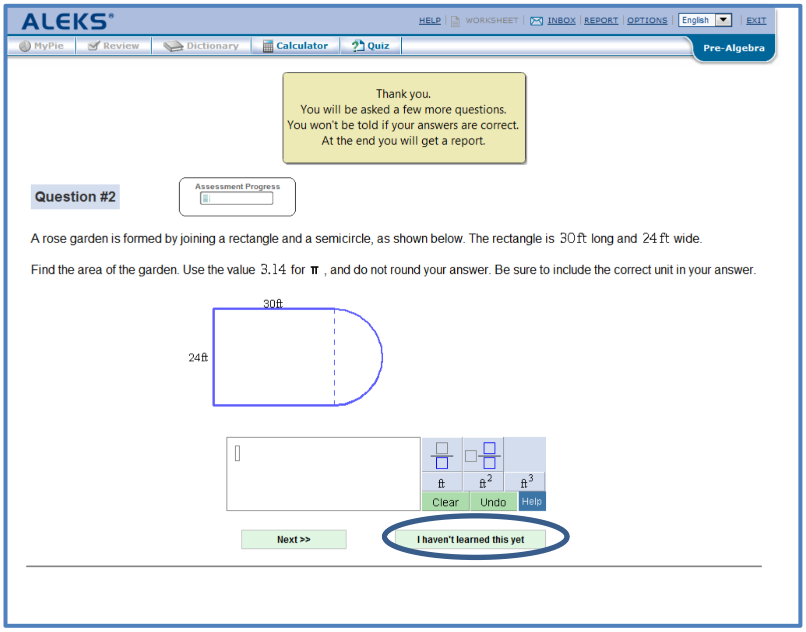


Figure 9: ALEKS pre-test for initial placement

Following the pre-test, the ALEKS system designed a customized learning plan for the individual student; this is known as the student's PIE. Figure 10 shows a sample learning pie based on completion of the initial system pre-test. As the student continued to practice, the system generated a progress report. The pie and progress report, shown in Figure 11, can be referred to by the student to determine progress toward topic mastery during all practice portions of the study plan, but not during a system-based assessment.

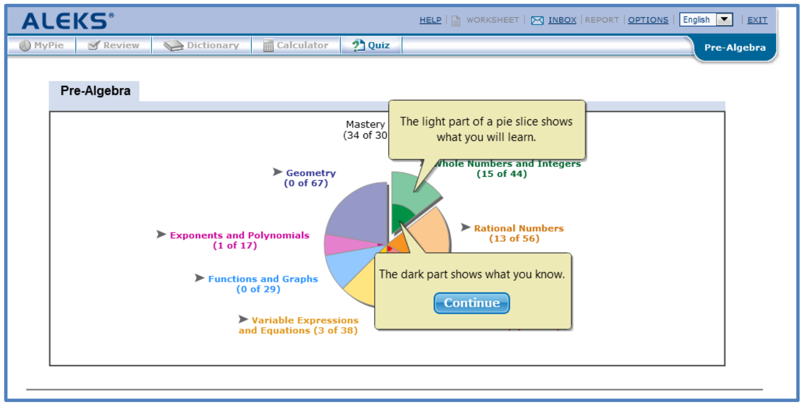


Figure 10: ALEKS learning pie

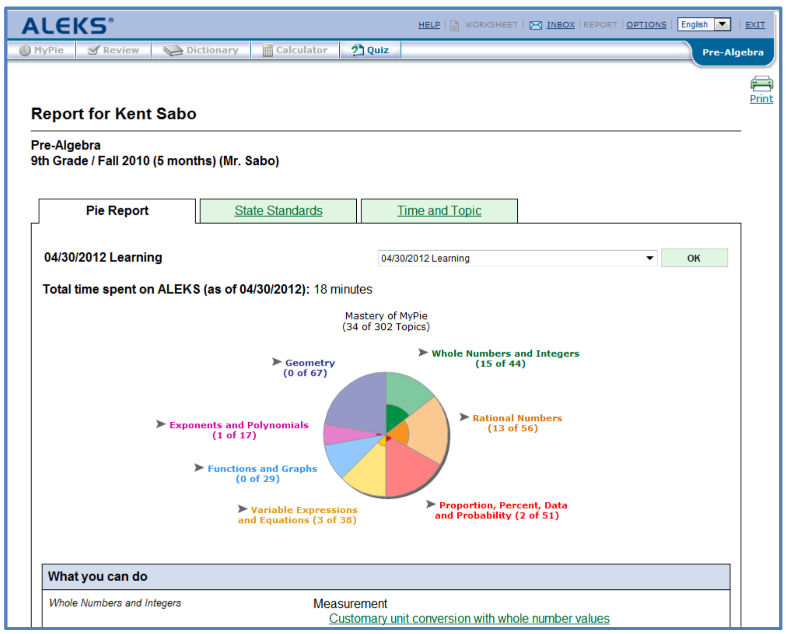


Figure 11: ALEKS progress report

As shown in Figure 12, the system provided the student a recommended first topic but allowed the student to select any topic he or she wanted to practice based on a determined level of the student's foundational knowledge determined during the pre-test. As shown in Figure 13, the system also produced a list of all topics the student was ready to learn upon completion of the pre-test and represented them in the PIE along with the topics the student would be ready to learn next. Below are sample screen shots of a first topic screen and a list of ready-to-learn next topics for an individual student. This list of topics can be used by the teacher also to gauge individual student progress and target help instruction.

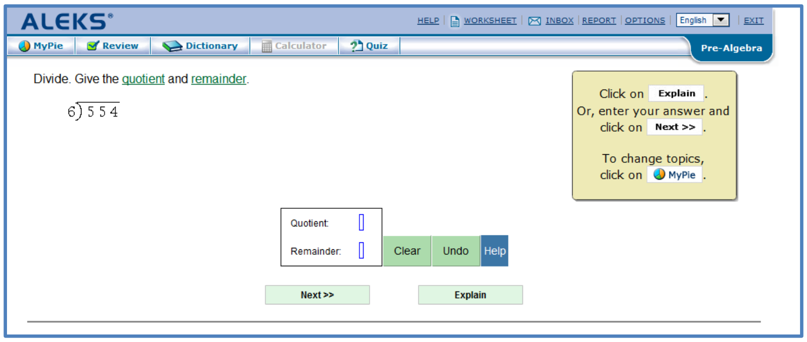


Figure 12: ALEKS first topic

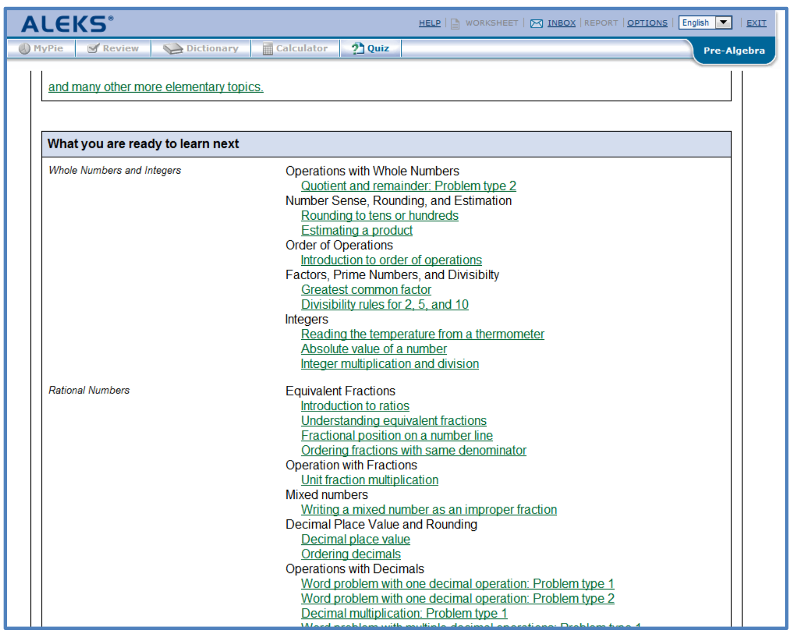


Figure 13: Topics student is ready to learn

The system provided several help features to instruct students on how to keystroke their answer inputs correctly. In Figures 14 and 15 are sample screen shots of the answer input help feature and a quick help reminder.

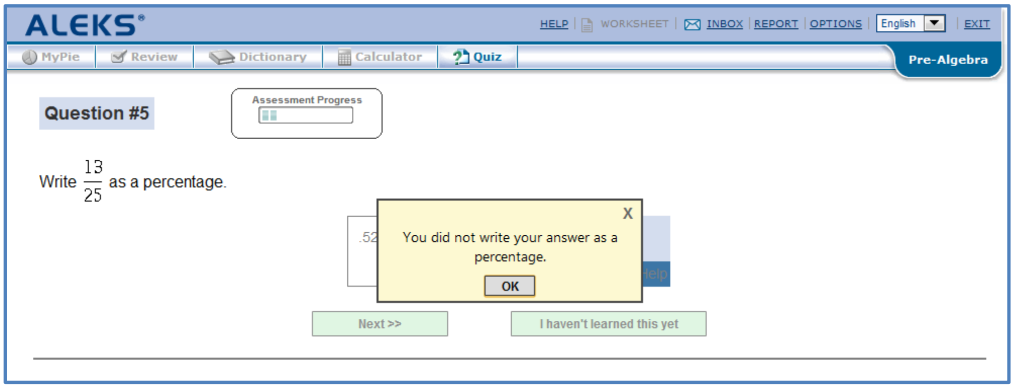


Figure 14: Answer input help feature

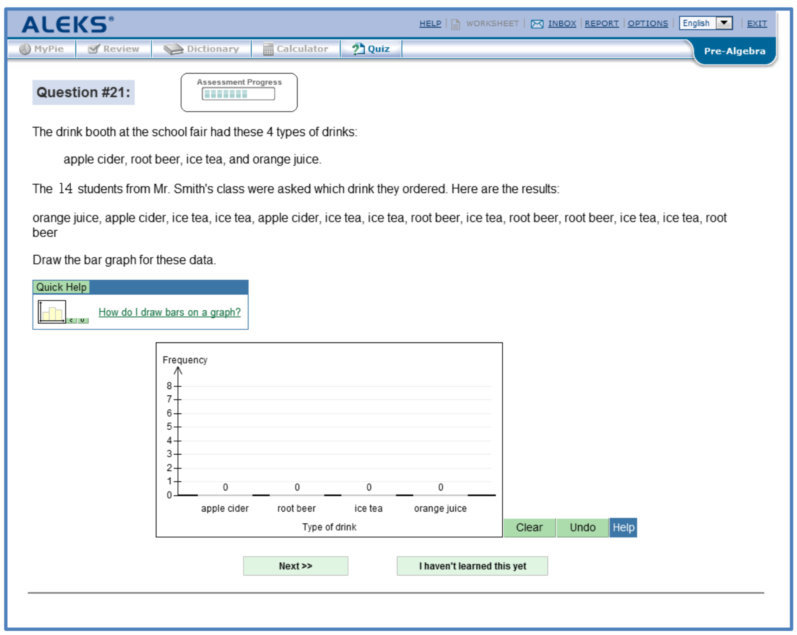


Figure 15: Quick help reminder

Finally, as shown in Figure 16, the system provided a list of review topics to suggest areas where students may need further instruction and practice. The system also displayed a list of review topics the student had currently mastered. These topic lists inform the work effort the student has completed and how much work effort or topic mastery remains to be completed. Work effort is not a reporting label used by the intelligent tutoring system but the definition of work effort used in this study is consistent with previous studies that measured work effort with an intelligent tutor as an indicator of student learning and course progress (Barrus et al., 2011).

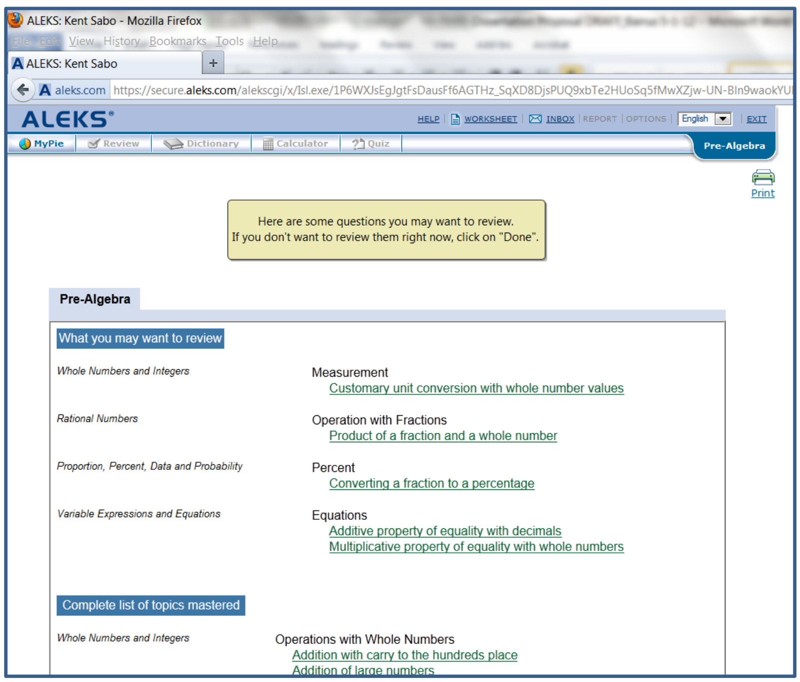


Figure 16: Suggested review topics and topics currently mastered

A basic back-end reporting tool is available to allow teachers to reference log data related to individual student performance. This log data is somewhat difficult to access since this is a commercial system and the raw data is proprietary but key reporting indicators such as number and type of topics mastered are helpful to providing predictive evidence of variables that have the most impact on math achievement.

Instruments

Classroom Observation Instrument

Three classrooms observations were completed for each section of the course. These observations were completed by the same observer each time. Refer to Appendix C to review a copy of the classroom observation instrument (Teach 21, 2012). The classroom observations were used to compile the study condition descriptions. This instrument was adapted to align with the needs of this study from teaching materials made available on the Teach 21 website (Teach 21, 2012).

SRL Instrument

Students completed a 76-item Learning and Study Strategies Inventory (LASSI) High-School version. This is a validated instrument specifically for measuring self-regulated learning attitudes and skills with high school students. The instrument is web-based and has been customized for high school students, which made it ideal to use in a high school Algebra course where web-based tools are being leveraged (Weinstein & Palmer, 1990). This instrument was purchased by the seat for students to complete and was not created as part of this study Refer to Appendix C to review sample items on the LASSI instrument and brief descriptions of the subscales analyzed in this study.

Motivation and Attitude Survey

Participants completed a demographic questionnaire including information about gender, preferred language and their prediction of the grade they would receive in their assigned course at the beginning of the Instructional Material Motivational Survey (IMMS), a 36-item, validated ARCS motivation/attitude survey using a 5-pt likert scale paired with five open-ended questions as a post-test (Keller, 2010). Refer to Appendix C of this document to review a sample of this instrument.

Learning Measure

The instrument used to measure learning was the Acuity Algebra product that is sold by McGraw Hill. (McGraw Hill Acuity Algebra). The Mesa School District holds a site license for this standardized testing product for use at Mesa High School. The system was made available for use during this study. This instrument was not created as part of conducting this study.

The Algebra teacher created a test aligned to the Algebra I curriculum covered in Fall 2012 from a test bank of standardized test items. Participants completed both the pre and post-tests using the Acuity standardized, web-based Algebra proficiency exam designed to assess algebra readiness, proficiency, and ongoing progress. Refer to Appendix C to review sample items from this instrument.

ACCUPLACER Reading Comprehension Placement Test

The ACCUPLACER reading comprehension assessment is usually used as placement exams for students entering college (Accuplacer.org). Due to its web-based, adaptive and intelligent nature, it is also very effective to pair with web-based, intelligent tutoring system evaluations since these systems rely on student's abilities to read and understand math problems and procedures. Refer to Appendix C to review sample items from this test.

Learning Connections Inventory

A 28-item self-report learning-patterns inventory known as the Learning Connections Inventory (LCI), which is part of the Let Me Learn® curriculum (Dawkins, Kottkamp, & Johnston, 2010), was administered as part of the pre-test. The purpose of the LCI is to provide participants and course instructors with insights and awareness into the patterns participants use to approach learning. Refer to Appendix F of this document to review sample items from the HS LCI.

Procedure

Participants were assigned from the population of remedial Algebra students by the high school registrar's office to one of three class periods. These three class periods were then randomly assigned conditions in the study. Because random assignment directly from the population to a study condition was not possible, this study is being categorized as quasi-experimental.

The consent forms were distributed and signed by students on the first day of class. The principal provided consent in lieu of parents because the study data was collected as part of the required curriculum for each version of the remedial Algebra course and the study was deemed by the IRB as exempt.

On Days 1-3 of the study, all students completed the initial battery of self-report instruments, including the demographic questionnaire, the LASSI SRL instrument, the Learning Connections Inventory (LCI), and the Acuity Algebra Pre-Test.

Beginning on Day 4 of the study, each section of the course began covering the introductory Algebra content. The SRL Tutorial + intelligent drill and practice course design class logged into the SRL modules and began completing that content for 20 minutes each class period followed by 30 minutes of practice in ALEKS, the intelligent tutor. Three observations were conducted in each study condition. They were scheduled with the classroom teacher two to three days prior to each observation and spread out to occur approximately at the beginning, middle, and end of the study.

At the end of the semester following approximately 90 scheduled school days of class periods lasting approximately 50-minutes each that comprised the remaining days of the study, participants completed the post-tests, including the Acuity Algebra post-test and the LASSI SRL post-test, and participants also completed an Instructional Materials Motivation Survey (IMMS) (Keller, 2010).

Scoring

All of the instruments were web-based and computer-scored with the exception of the Learning Connections Inventory (LCI). This instrument was hand-scored.

Chapter 3

RESULTS

Data Analysis Summary by Research Question

Research Questions #1 and 2

- Does self-regulated learning instruction provided in conjunction with an intelligent algebra tutor increase students' self-regulated learning skills, math achievement, and motivation more than the tutoring system alone?
- Does an intelligent algebra tutor increase math achievement over classroom instruction (i.e., business-as-usual control design condition)?

One-way ANCOVAs were conducted to measure whether the difference between the group means of the three study conditions were significantly different while controlling for prior knowledge, motivation, or self-regulated learning skills. An adjustment procedure was used based on the reliability of each measure to increase the robustness of the one-way ANCOVA against the violation of the random assignment of subjects' assumption. After completing this adjustment procedure ("Research Methods Knowledge Base," 2013), the three assumptions underlying one-way ANCOVA analyses including normal distribution of the dependent variables, homogeneity of slopes and independence of subjects were assessed and determined to be met prior to conducting the ANCOVA analyses.

Research Question #3

- To what extent are student descriptives, SRL skills, learning patterns, motivation, persistence, work effort and the ARCS materials survey results predictive of changes in SRL skills, math learning achievement, and motivation after participating in a remedial Algebra course?

Log data was collected from the intelligent tutor that measures work effort. Work effort refers to the amount of Algebra content students mastered during their participation in the course. School attendance data was used to indicate persistence and the ARCS motivation instructional materials survey was used to collect attention, relevance, confidence, and satisfaction predictor data points. This data along with all of the other independent variables, including participant descriptives, SRL skills, and LCI learning patterns, was analyzed using three multiple regression models to determine which of the model is most predictive of improved self-regulated learning skills, increased math achievement, and improved motivation, along with determining the relative predictive contribution that each variable provides to improving SRL skills, increasing math learning achievement, and improving motivation. The multiple regression models have been labeled the ARCS motivation model, the demographic model, and the learning skills model. This analysis is exploratory and is intended to determine if there are linkages between demographics, ARCS motivational design and learning skills, outcomes in SRL skills, motivation, and math achievement that can be made along with suggestions for future studies derived.

The three assumptions of the fixed-effects multiple correlation coefficient, normality, random assignment, and independence, were assessed and threats to validity explained.

Attrition Rates

Each group experienced varying levels of attrition, based on student attendance, and eligibility for computer access, based on behavior at school. Refer to Table 1 to review the specific attrition rates by dependent measure and condition. On the achievement dependent measure, the average attrition rate across all three conditions was 46.6%. On the SRL/motivation dependent measures, the average attrition rate across all three conditions was 40%.

Students may have lost computer access privileges that impacted their ability to participate in the study on various days throughout the semester. Students may also have been expelled, dropped out of high school, or transferred to another school. These average attrition rates are comparable with the attrition rate observed in similar studies that focus on a remedial population.

Demographic Data Summary

The following demographic data was compiled using an exit survey, the official course attendance records and the intelligent tutor log data. Persistence in the course summarized in Table 5 refers to attendance and whether students remained in the course rather than dropping out or transferring to another school. This data does not indicate whether they were present to participate in each of the dependent measures. Thus, attendance or persistence in the course is different than attrition in dependent measure participation. There were students absent or that had already been dropped from the study when this data was compiled. The sample size for the survey was 49 participants. The sample size for attendance was 40. The sample size for work effort was 43. Percentages have been rounded.

Table 4

Expected Grade in Course

Value	Percentage
A	16%
B	36%
C	34%
D	7%
F	7%

Table 5

Persistence in Course by Study Condition

Value	Percentage
Control Course Design	88%
Intelligent, Web-Based Practice Only Course Design	93%
Web-Based, Intelligent Tutor +SRL e-Learning modules Course Design	95%

Table 6

Work Effort in the Intelligent Tutor

Value	Percentage
Control Course Design	N/A
Intelligent, Web-Based Practice Only Course Design	33%
Web-Based, Intelligent Tutor +SRL e-Learning modules Course Design	36%

It is important to remember that all of the students in the study were repeating an Algebra I course and started below grade level in terms of Algebra proficiency. Algebra learning occurred in all three versions of the course but the SRL + Intelligent tutor group gained the most in terms of mastery of foundational Algebra skills as reported by the intelligent tutoring system and the course final exam that will best prepare students for second semester as well as additional math courses throughout their high school career. It is also important to note that because students did not come to this course with the necessary prerequisite knowledge and skills, they did make progress in learning Algebra I but still did not reach grade level or align to national standards.

Table 7

ALEKS end-of-semester mastery levels aligned to National Algebra Levels (NSF.gov, 2012)

Study Condition	ALEKS Mastery	NSF Algebra Level
Control Course Design	N/A	Level 1-3
Intelligent, Web-Based Practice Only Course Design	• *Arithmetic Readiness (61%)* • *Real Numbers and Linear Equations (43%)* • Functions and Systems of Equations (11%) • Polynomials and Quadratic Equations (1%) • Exponents and Square Roots (10%) • Data Analysis and Probability (8%)	Level 1-3
Web-Based, Intelligent Tutor +SRL e-Learning modules Course Design	• *Arithmetic Readiness (72%)* • *Real Numbers and Linear Equations (51%)* • Functions and Systems of Equations (15%) • Polynomials and Quadratic Equations (1%) • Exponents and Square Roots (15%) • Data Analysis and Probability (7%)	Level 1-3

ANCOVA Results

Achievement. A one-way analysis of co-variance (ANCOVA) was conducted using the pre-test score as the covariate that helps takes into account that random assignment was not available and the groups are assumed to not be equivalent ("Research Methods Knowledge Base," 2013). The independent variable included three levels: the control course design, the intelligent tutor only course design and the SRL e-learning modules+ intelligent tutor course design. The dependent variable was math achievement and the covariate was the Acuity Algebra pre-test. The assumptions for ANCOVA were met. In particular, the homogeneity of the regression effect was evident for the covariate, and the covariate was linearly related to the dependent measure. The

ANCOVA was not significant, F (3,50) = 2.257, p= .099, *d*= .52, η_p^2= .16. The estimated strength of the relationship between course version and the dependent variable was strong, as assessed by η_p^2, with the math achievement factor accounting for 16% of the variance in the math achievement dependent measure, holding constant the Acuity Algebra pre-test scores that takes into account the Algebra knowledge that students had prior to completing their assigned course. The mean Acuity Algebra achievement scores adjusted for initial differences were ordered as expected across the course design study conditions. The SRL + intelligent drill and practice course design group had the largest adjusted mean (M= 9.39), the control course design group had a smaller adjusted mean (M= 8.65), and the intelligent drill and practice only course design group had the smallest adjusted mean (M= 7.21).

Motivation. A one-way analysis of co-variance (ANCOVA) was planned using an adjusted pre-test score as the covariate that takes into account that random assignment was not available and the groups are assumed to not be equivalent ("Research Methods Knowledge Base," 2013). The independent variable included three levels: the control course design, the intelligent tutor only course design and the SRL e-learning modules+ intelligent tutor course design. The dependent variable was the SRL motivation post-test measure and the covariate was the SRL pre-test measure. The assumptions for ANCOVA were not met. In particular, the homogeneity of the regression effect was violated for the covariate, and the covariate was not linearly related to the dependent measure.

Based on the violation of the homogeneity of variance assumption, simple main effects tests were conducted that allow for heterogeneity of slopes rather than ANCOVA. Simple main effects tests were conducted to assess differences among groups at low (1 SD below the mean), medium (mean), and high (1 SD above the mean) values on the covariate. A p value of .017 (.05/3) was required for significance for each of these tests. If any of simple main effect was significant, pairwise comparisons were evaluated at the same level (i.e., .017) as the simple main effects test, following the LSD procedure.

The simple main effects test was not significant for a low value on the motivation pre-test, F (2,38) = 2.99, p=.063, η_p^2= .14, the medium value on the motivation pre-test F (2,38) = .96, p=.39, η_p^2= .048 or the high value on the motivation pre-test, F (2,38) = 3.57, p=.038, η_p^2= .158. The strength of the relationship between motivation at the end of the semester and course design condition was strong, as assessed by η_p^2, with the control course design condition accounting for 16% of the variance of the motivation at the end-of-the-semester dependent variable.

Self-Regulated Learning (SRL): Attitude. A one-way analysis of covariance (ANCOVA) was conducted using pre-test score as the covariate that takes into account that random assignment was not available and the groups are assumed to not be equivalent. The independent variable included three levels: the control course design, the intelligent tutor only course design and the SRL e-learning modules+ intelligent tutor course design. The dependent variable was an SRL-based post-test measure of attitude and the covariate was the SRL-based pre-test measure of attitude. The assumptions for ANCOVA were met. In particular, the homogeneity of the regression effect was evident for the covariate, and the covariate was linearly related to the dependent measure. The ANCOVA was not significant, F (2,40) = 2.4, p= .106, d=.45 η_p^2 = .11. The strength of the relationship between course design and the dependent variable was moderate, as assessed by η_p^2, with the SRL attitude factor accounting for 11% of the variance in the SRL-based attitude dependent measure, holding constant the SRL-based pre-test scores that take into account SRL attitudes students had prior to completing their assigned course. The mean attitude pre-test scores adjusted for initial differences were ordered somewhat as expected across the course design study conditions. The intelligent drill and practice only course design group had the largest adjusted mean (M= 28.74), the SRL + intelligent drill and practice course design group had a smaller adjusted mean (M= 25.43) and the control course design group had the smallest adjusted mean (M= 27.73).

Self-Regulated Learning (SRL): Information Processing. A one-way analysis of co-variance (ANCOVA) was conducted using an adjusted pre-test score as the covariate that takes into account that random assignment was not available and the groups are assumed to not be equivalent. The independent variable included three levels: the control course design, the SRL + intelligent drill and practice course design, and the intelligent drill and practice only course design. The dependent variable was an SRL-based post-test measure of information processing skills and the covariate was an SRL-based pre-test measure of information processing skills. The assumptions for ANCOVA were met. In particular, the homogeneity of the regression effect was evident for the covariate, and the covariate was linearly related to the dependent measure. The ANCOVA was not significant, $F\,(2,38) = 2.40$, $p= .10$, $d=.46$, $\eta_p^2= .11$. The strength of the relationship between course version and the dependent variable was moderate, as assessed by η_p^2, with the math achievement factor accounting for 11% of the variance in the SRL-based information processing dependent measure, holding constant the SRL-based information processing pre-test scores that takes into account information processing knowledge students had prior to completing their assigned course. The mean SRL-based information processing scores adjusted for initial differences were ordered across the course design study conditions with the control course design condition having the largest adjusted mean (M= 25.38), the SRL e-learning modules course design condition having a smaller adjusted mean (M= 23.61) and the intelligent tutor only course design group having the smallest adjusted mean (M= 22.66).

Exploratory Multiple Regression Analyses

Model 1: ARCS Motivation Variables with SRL Attitude. A simultaneous multiple regression analysis was conducted to evaluate how well the ARCS motivation variables predicted the SRL-based attitude post-test score. The predictors were the four components of the ARCS motivation model, attention, relevance, confidence, and satisfaction, while the criterion variable was the SRL attitude post-test score. The linear combination of the ARCS motivation model measures was significantly related to the SRL-based attitude post-test score, $F\,(4,29) = 3.30$, $p= .024$. The sample multiple correlation coefficient was .218, indicating that approximately 22% of the variance of the SRL-based attitude post-test score can be accounted for by the linear combination of the ARCS motivation model measures.

Table14 presents the indices to indicate the relative strength of the individual predictors. All the bivariate correlations between the ARCS motivation measures and the SRL attitude post-test score were positive except satisfaction and attitude, which is as expected because a low satisfaction in the course would most likely decrease a student's attitude. Only two of the four ARCS motivation model partial correlations are statistically significant ($p<.05$): relevance and satisfaction. On the basis of these correlational analyses, it is tempting to conclude that only relevance and satisfaction are useful predictors for the SRL-attitude measure, as they accounted for 32% and 48% of the variance respectively. However, judgments about the relative importance of all four of these predictors are difficult because they are correlated.

Table 14

Bivariate and Partial Correlations of the Predictors with SRL-Attitude Post-Test

Predictors	Correlation between predictor and the SRL attitude index	Correlation between each predictor and the SRL attitude index controlling for all other predictors
Attention	.27	.25
Relevance	.22	.36*
Confidence	.23	.21
Satisfaction	.-11	.50**

**p<.05, **p<.01*

Model 2: Mastery Learning Variables Model With Achievement. A simultaneous multiple regression analysis was conducted to evaluate how well independent variables combined to create a mastery learning variables model that predicted the Algebra achievement post-test score. The predictors were English language, Spanish language, LCI Pattern: Confluence, Reading Comprehension, Persistence, and Work Effort while the criterion variable was the Algebra achievement post-test score. The goal of this model was to understand which variables have the most impact on a student's ability to master content within an intelligent tutoring system. The linear combination of the learning variables model measures was not significantly related to the Algebra achievement post-test score, $F\,(6,60) = 2.00$, $p = .079$; however, this could be attributed to low power due to a small sample size. The sample multiple correlation coefficient was .084, indicating that approximately 8% of the variance of the Algebra achievement post-test score can be accounted for by the linear combination of the learning variables model. This is a small effect size, which indicates that a further refinement of the model should be explored.

Table15 presents the indices to indicate the relative strength of the individual predictors. As expected, the language related learning variables were negatively correlated with the Algebra achievement post-test measure, which validates the importance of language in math learning. The LCI Pattern: Confluence was also negatively correlated with the Algebra achievement post-test score, which indicates that students who are innovative and driven by new ideas may have some difficulty achieving in Algebra because it requires more sequence and precision traits to follow problem-solving processes. Reading Comprehension, Persistence, and Work Effort are all positively correlated with the Algebra achievement post-test score, which is expected because an increase in these abilities should contribute well to increases in learning achievement. However, these correlations are unexpectedly weak, which indicates that a more refined learning variables model may need to be explored. Only two of the learning variables model partial correlations are statistically significant ($p<.05$): English and Spanish language. On the basis of these correlational analyses, it is tempting to conclude that only the language related variables are useful predictors for the Algebra achievement post-test measure, as they accounted for 26% and 23% of the variance respectively. However, LCI Pattern: Confluence, Reading Comprehension, and Persistence accounted for 17%, 13% and 17% of the variance respectively as well, which can be considered medium-sized effects. Judgments about the relative importance of these predictors are difficult because they are correlated; however, in the case of this learning variables model, Language and Reading Comprehension have the strongest correlations with the Algebra achievement post-test score.

Table 15

Bivariate and Partial Correlations of the Predictors with Algebra Achievement Post-Test

Predictors	Correlation between predictor and the Algebra achievement post-test score	Correlation between each predictor and the SRL attitude index controlling for all other predictors
English Language	-.008	-.27*
Spanish Language	-.05	-.25*
LCI Pattern: Confluence	-.19	.18
Reading Comprehension	.17	.15
Persistence	.19	.18
Work Effort	.16	.091

**p<.05, **p<.01*

Model 3: Demographic Variables Model with Motivation. A multiple regression analysis was conducted to evaluate how well independent variables combined to create a demographic model that predicted the motivation post-test score. The predictors were English language, Spanish language, LCI Pattern: Confluence, and Gender, while the criterion variable was the motivation post-test score. The linear combination of the learning variables model measures was significantly related to the motivation post-test score, $F\,(6,60) = 4.30$, $p = .001$. The sample multiple correlation coefficient was .231, indicating that approximately 23% of the variance of the Algebra achievement post-test score can be accounted for by the linear combination of the demographic variables model.

Table 16 presents the indices to indicate the relative strength of the individual predictors. As expected, the language related learning variables were negatively correlated with the motivation post-test measure, which validates the importance of language in math learning. The LCI Pattern: Confluence was also negatively correlated with the motivation post-test score, which indicates that students who are innovative and driven by new ideas may have some difficulty achieving in Algebra because it requires more sequence and precision traits to follow problem-solving processes, and this learning pattern, if not understood, may decrease their learning motivation. Gender is positively correlated with the motivation post-test score, although the correlation is very weak. Only two of the learning variables model partial correlations are statistically significant ($p<.05$): English and Spanish language.

However, the LCI Pattern: Confluence is very close to being significant. On the basis of these correlational analyses, it is tempting to conclude that only the language-related variables are useful predictors for the Algebra achievement post-test measure, as they accounted for 48% and 46% of the variance respectively. However, LCI Pattern: Confluence and Gender accounted for 21%, 14% of the variance respectively as well, which can be considered medium-sized effects. Judgments about the relative importance of these predictors are difficult because they are correlated; however, in the case of this demographic variables model, language and LCI Pattern: Confluence have the strongest correlations with the motivation post-test score.

Table 16

Bivariate and Partial Correlations of the Predictors with Motivation Post-Test

Predictors	Correlation between predictor and the Algebra achievement post-test score	Correlation between each predictor and the SRL attitude index controlling for all other predictors
English Language	-.06	-.50
Spanish Language	-.06	-.49
LCI Pattern:Confluence	-.24	-.24
Gender	.01	-.17

*$p<.05$, **$p<.01$

Chapter 4

DISCUSSION

Discussion of Main Purpose

The purpose of this study was to run a field-based course evaluation study to collect empirical evidence of the impact of three different course designs on remedial Algebra student achievement in math, motivation to learn math and self-regulated learning skill development in the day-to-day high school setting. The department chair and other Algebra instructors wanted to determine if course design changes would be beneficial to increasing Algebra achievement, motivation, and SRL skills and district personnel were interested in evaluating the effectiveness of investing in web-based intelligent tutors to use for high school Algebra remediation. Overall, the study yielded very interesting results that have contributed well to remedial course improvement within the Mesa High School math department.

For example, the teacher and the department chair decided to structure the intelligent tutoring practice sessions in the second semester portion of the course more tightly by providing students a checklist to guide practice goals. The teacher also provided more detailed explanation to help students not be frustrated by the regularity of the assessments in the ALEKS tutor. She explained that the tutor provides the right level of practice for students to master concepts and prepare them for the next section in the tutor as well as for the course final exam. Finally, she decided to incorporate additional self-regulated learning principles into the business-as-usual course design to try to help students self-guide the practice portion of those class sessions better and in the tutor-based course conditions she decided to demonstrate and model specific math concepts and processes to the class as a whole to more efficiently address trends in student questioning and misunderstanding. These changes allowed the teacher to apply learner-focused instructional strategies in all versions of the course.

I would also recommend to Mesa High School as well as other remedial course designers and instructors to take a more hybrid approach to designing and delivering math instruction going forward. This study indicates that is does seem to add value to provide self-regulated learning instruction that provides students the opportunity to be more aware of their practice habits and goals. I would recommend that the Mesa School District continue to purchase ALEKS licenses as the investment is very similar to math textbooks. However, an additional investment I believe would be necessary is to provide professional development related to the effective implementation of intelligent tutors in the math classroom as well as instruction about how to provide self-regulated learning instruction and practice to help scaffold student practice with an intelligent tutor. I would also recommend that remedial Algebra I be broken up into four semesters, if possible, to allow students more time to work through the material and remediate prior to trying to force them to move on into more difficult Algebra skills without the appropriate prerequisite knowledge.

Finally, I would recommend that the relevance of the Algebra skills and knowledge be emphasized more heavily and that a textbook or web-based, interactive tool that contains math for the trades such as construction, engineering, design, and other applied math fields be used to demonstrate how math is applied in real-world settings to help guide student career exploration and goal setting in their personal lives.

Findings by Research Question

Does self-regulated learning instruction provided in conjunction with web-based, intelligent practice increase students' self-regulated learning skills, math achievement, and motivation more than the intelligent, web-based practice alone controlling for prior Algebra knowledge, motivation and self-regulated learning skills?

Previous research on SRL training and its impact on self-regulated learning skills, motivation, and achievement has shown that implementing specific SRL-related training that teaches students how to be successful in their practice and test-taking endeavors does help students improve their learning outcomes (Azevedo & Cromley, 2004). This study extends that research by investigating these claims in a field setting rather than a laboratory setting. The web-based SRL training was designed to be simple, straight-forward and engaging by adhering to the principles of the ARCS motivation instructional design model (Keller, 2010) and the Let Me Learn learning pattern curriculum (Dawkins et al., 2010).

The ANCOVAs run to determine group differences in levels of math achievement, motivation and self-regulated learning were not significant but it appears based on observed power that study attrition that resulted in a modest sample size in the present study may have played a role in limiting the significance of some of the statistical comparisons conducted. However, observed lack of power is not the only issue that limits the significant findings of this study. The study design also needs to be improved to capture significant differences between groups aligned to the research question. The first step would be to determine how to specifically improve the self-regulated learning course design to potentially make it more sensitive to improving student Algebra achievement, motivation and self-regulated learning skills than the standard Algebra course or intelligent tutor practice alone course designs.

The moderate to strong effect-size estimates on the ANCOVAs that measured group differences in terms of math achievement, motivation and improvement in self-regulated learning skills indicate evidence that course designs using web-based intelligent practice tools need to be even more tightly structured and scaffolded in order to maintain and increase student motivation especially within a remedial population.

This finding was supported by the classroom observations and interview with the teacher as well. The classroom management within the tutor-based course conditions was more difficult and more disruptions occurred due to the heavy reliance on students to regulate their own practice. The teacher would move throughout the classroom assisting students and reminding them to stay on task, however, if the teacher stopped to help one student with a specific question other students had a tendency to become distracted and go off task. The teacher noted during our unstructured interview or debriefing session that she felt the students used adequate help seeking skills in the tutor-based conditions but they seemed to get distracted much more easily and many students struggled to stay on task throughout a practice session.

Another interesting thing to note based on classroom observation and discussion with the teacher is that in the SRL e-learning module + tutor course design, students seemed to decrease in motivation during the semester because they were less apathetic about their individual responsibility for their learning and achievement. As students began to accept and take ownership for their learning and become engaged in the practice process, they were prone to become initially overwhelmed by their increased understanding about the gap between what they knew and what they still needed to learn in order to be able to pass the course.

Work effort within the intelligent tutoring system in the SRL e-learning modules version of the course was higher than the intelligent only version of the course which indicates the potential impact of including self-regulated learning instruction. Again, work effort refers to number of topics mastered within the system. This finding demonstrates that more work was completed in the intelligent tutor in the self-regulated learning version of the course even though there was less time allocated to math practice during each class session due to the twenty minutes allocated to self-regulated learning instruction each day. This means that students in the self-regulated learning version of the course mastered more Algebra topics within the intelligent tutoring system and were potentially better prepared to continue learning in the second semester of the course and in other math courses.

Does an intelligent algebra tutor increase math achievement over classroom instruction controlling for prior Algebra knowledge (i.e., business-as-usual control course design)? The results of this study do not provide enough evidence that using an intelligent tutor alone, without scaffolding and support in the form of self-regulated learning instruction, is more effective than a business-as-usual remedial course design. Observationally it seems that certain types of students can learn and achieve well using an intelligent Algebra tutor alone to practice if they have the proper foundational math skills and the self-efficacy and motivation to facilitate their own practice effectively.

A greater emphasis on a thorough audience analysis prior to implementing an intelligent tutor only course design would be recommended to determine knowledge and skills of students both in self-regulation and Algebra prior to commencing their participation in this type of course or practice environment. A battery of effective evaluative instruments needs to be compiled which may include the LCI, the ARCS motivation measure, a reading comprehension measure and an Algebra pre-test measure.

Teachers need to be trained to administer and understand the results of the evaluative battery of tests. Since time is usually limited in a remedial, high school classroom, technology should be used to determine how to make this process as efficient as possible during the student participation as well as the reporting portions of completing the battery of tests and analyzing the results.

To what extent are student descriptives, SRL skills, learning patterns, motivation, persistence, work effort, and the ARCS materials survey results predictive of changes in SRL skills, math learning achievement, and motivation after participating in a remedial Algebra course?

The exploratory, simultaneous multiple regression analyses were run using preliminary audience analysis approaches to create models grouped by ARCS motivation-related, mastery and demographic variables. The ARCS motivation model included each of the factors that make of the ARCS model including attention, relevance, confidence and satisfaction. The demographic variables included attributes inherent to the students themselves such as gender, age learning pattern preference and primary language spoken at home. The learning variable model was aligned to areas that based on the literature as well as classroom observation and discussions with the teacher, highlighted areas that I hypothesized would be major moderating factors in the learning process, such as language and reading comprehension but this model included learning pattern preference as well.

The exploratory, simultaneous multiple regression analyses based on the three previously explained models confirmed that the independent variables included in this study are appropriate predictors of learning achievement, motivation and self-regulated learning skills. Again, an improved audience analysis process and battery of tests would allow future studies to be refined based on the most predictive variables within a specific sample.

These analyses also yielded some unexpected predictor variables that are worth exploring in future studies. For example, the LCI Learning Pattern: Confluence is a very interesting predictor variable in that it is negatively correlated with both achievement and motivation. This indicates that in an Algebra course it is vital for students with a use-first confluent learning pattern to be aware of the information processing learning strategies that they will need to adopt to be successful in math, which is a predominately sequence and precision learning pattern environment. This indicates also that students with the "use first" sequence and precision learning patterns can also be educated on how to "play to their strengths" and view math as a problem-solving, detail-oriented process (Dawkins et al., 2010).

Study Strengths and Limitations

The main strengths and limitations of this study are related to external and internal validity. Validity refers to how confident a researcher can be in his or her claims (Shadish, Cook, & Campbell, 2002). Internal validity of a study design controls for bias within the study to ensure that results are achieved based on effects of the intervention. External validity of a study design refers to how well the results of the study can be generalized to the intended population. (Shadish et al., 2002).

External Validity

The external validity of this study is a major strength because the results can be generalized to help inform course design using intelligent tutors in other remedial math settings since we were able to conduct observations and work directly with samples from our intended population rather than samples of convenience. These study factors increased the external validity of the results which means we can apply what we have learned here in other remedial, Algebra classrooms of a similar demographic make-up.

Internal Validity

Due to the nature of field studies that are often not as easily controlled as a laboratory research setting there were some potential threats to internal validity inherent in the requirements of the study design. The first potential threat to internal validity in this study could potentially be selection bias. The intervention groups were based on classes created by the high school registrar's office and it was not possible to use random assignment due to scheduling constraints. Statistical procedures that account for the lack of random assignment and potentially unequal groups were used to help mitigate this threat to validity. ("Research Methods Knowledge Base," 2013).

The second potential threat to validity was participant attrition during the course of the study. This is potentially the most impactful threat to validity within this study especially due to its impact on statistical power. Due to the field nature of the study where students drop out, change schools, or in some cases are suspended or expelled, it is very difficult to control attrition. The nature of the study that focused on educating students about being more self-regulated learners who take responsibility for their own learning processes was intended to help control attrition. It was only somewhat effective in this case. This is a threat to validity that needs to be explored further when planning additional field studies in a high-school setting.

The third threat to internal validity in this study was the lack of statistical power needed to obtain significant results. Effect size interpretation within this study provides evidence that increasing the sample size in order to increase statistical power may allow discovery of additional significant findings that indicate causal relationships between the intervention and the dependent measures.

In spite of the threats to internal validity inherent in this field-based study design, the nature of studying the effectiveness of interventions with the actual population enhances the external validity or ability to generalize the findings to a similar population. In this case where the results are intended to assist in improving remediation curriculum going forward, effect size estimates are helpful in determining how resources should be allocated to refine the field study design going forward. Field studies are valuable when conducting curriculum evaluations as they can often provide research efficiency in data collection while providing a positive learning influence for teachers and students during the research process.

Recommendations for Future Study

There are many possibilities for future study in the areas of self-regulated learning and web-based intelligent practice environments. It may be that a more hybrid approach to course design may work better to compare course designs that are more similar than they are different to try to establish what the most effective course design might be that focuses on improving Algebra achievement using self-regulated learning instruction that is more specified to increasing information processing and test taking skills. In terms of information processing skills related to improving self-regulated learning, it would be helpful to refine the study to focus on design and evaluation of math and web-based practice environment strategies only rather than teaching a more comprehensive self-regulated learning tool set. This focus would allow course designers and instructors to determine which math study strategies are most impactful in improving information processing and test-taking skills.

The areas that hold the most interest for me going forward in order to improve the efficiency and practicality of the study design are SRL context and skill alignment which refers to improving the SRL e-learning module instruction and testing a massed instruction and practice approach to delivering the SRL instruction. It would also be valuable to use the ARCS model to continue to improve and further align the self-regulated learning instruction to increase relevance and better assist students to transfer self-regulated learning skill development to math performance and mastery.

It would also be useful to explore additional instructional strategies for chunking the content and increasing the interactivity in meaningful, engaging ways based on student feedback using lab-based studies that leverage biometric sensors or eye tracking systems to measure student engagement beyond self-report measures. It is also vital to explore feature enhancements that improve reporting of student engagement with the system to understand better how meaningful student interaction with the self-regulated learning content really is.

It is also important to note that the current self-regulated learning course design may not adequately take into account the varied reading and language skills of the students. The online tools used in this study relied heavily on reading and writing in English which is a requirement in all Mesa Public Schools classrooms. Future studies that have a high population of non-English speakers would benefit from looking to the English as a Second Language and/or reading comprehension literature and work to align it as closely as possible with the self-regulated learning literature. A study like this may be more practical to run first in a laboratory setting where intervention materials can be delivered in the student's preferred language and evaluated for effectiveness. Additional specificity in the design of the SRL instructional materials and selection of the instruments based on language preference may also be necessary to further refine this type of study in a field setting.

In terms of motivation and attitude as it relates to a student's willingness to take responsibility for his or her own learning, courses need to be designed to remove additional barriers to student success, which will in turn reduce student frustration. This may involve designing courses with tighter scaffolding and teacher structure while still allowing increased locus of control within web-based intelligent practice environments for students. Since there are many instructional activities that can impact student learning, this study makes it difficult to attribute changes to student achievement, motivation and self-regulated learning skills to one specific course design. It would be interesting to refine the focus and study how SRL instruction impacts self-efficacy and attitude and how these variables in turn impact motivation and Algebra achievement across several types of course designs. For example, studying the effect of SRL instruction across multiple standard instruction classrooms and compare those classrooms to multiple intelligent tutor-enhanced classrooms.

The design, development and evaluation of an intelligent, Algebra-specific self-regulated learning system that includes a robust back-end reporting tool would be valuable to allow customized delivery, practice and mastery of self-regulated learning skills in conjunction with Algebra practice and mastery. This study could be used to inform intelligent tutor development that more fully integrates mastery of self-regulated learning skills with SRL attitude measures, engagement tracking and mastery assessments using Algebra contexts and applications. An integrated system would reduce the tool set required in the classroom and provide teachers with more customized feedback about each student's progress that can be shared with parents, counselors and other teachers in an effort to further assist remedial students.

It is also important to continue to plan the study design to try to reduce attrition as much as possible. Also, partnering with additional instructors to recruit more classes would allow for a larger initial sample size that would increase the power of the study design which may result in a greater likelihood of discovering statistically significant results.

In terms of designing studies to improve math achievement and help remedial students acquire the foundational math understanding required to succeed in higher levels of math, the content may need to be massed rather than distributed to provide a more supportive context earlier on in the course for students to properly implement self-regulated learning strategies as they make their way through the course. The SRL and Algebra content may also need to be chunked further and practiced longer, which would require a change in the way a two-semester Algebra course is paced. It also may be beneficial to design and evaluate a remedial Algebra course that is more focused on real-world, relevant math skills for the trades rather than an academic math track.

Finally, it would also be beneficial to complete additional exploratory multiple regression analyses on the existing data set to further narrow the scope of the variables and design studies that are able to be more efficiently executed in a field classroom by a field Algebra instructor, perhaps using an action research design approach. Overall, effect-size estimates seem to indicate that it is worthwhile to further explore self-regulated learning instruction that includes practicing information processing and test taking skills to help students increase math achievement over traditional classroom instruction and reap the benefits that web-based intelligent practice environments provide, including customizing learning and practice for each student.

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APPENDIX A

IRB APPROVAL

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Robert Atkinson BYENG
From:	Mark Roosa, Chair Soc Beh IRB
Date:	08/13/2012
Committee Action:	**Exemption Granted**
IRB Action Date:	08/13/2012
IRB Protocol #:	1207008083
Study Title:	Does Self Regulated Learning Skills Training Improve High School Students Self Regulation, Math Achievement, and Motivation While Using an Intelligent Tutor?

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(1) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.

APPENDIX B

INSTRUMENT PERMISSIONS

March 13, 2013

Angela Barrus
3857 E. Harmony Ave.
Mesa, AZ 85206

Dear Ms. Barrus:

I hereby grant permission for a one time use of a photocopied version of the LCI Form II (adapted), the copyrighted intellectual property of Learning Connections Resources, to be placed in the appendices of the dissertation: *Does Self-Regulated Learning Skills Training Improve High-School Students' Self-Regulation, Math Achievement, and Motivation While Using An Intelligent Tutor?*

The copy of the LCI Form II appearing in the appendices should be labeled **"Not for Distribution. This content is the intellectual property of Learning Connections Resources and may not be reproduced, distributed in any form including electronic or digital, published, resold, or used commercially in any manner without written permission from Learning Connections Resources."**

Christine A. Johnston

Digitally signed by Christine A. Johnston
DN: cn=Christine A. Johnston, o=Let Me Learn, ou, email=johnstca@comcast.net, c=US
Date: 2013.03.13 12:30:36 -04'00'

Christine A. Johnston
Learning Connections Resources, LLC partner
And Originator and Lead Researcher
Let Me Learn, Inc.

cc.
Dr. Robert K. Atkinson
Arizona State University
Sch Compt Infor & Dec Sys Engr Faculty
P.O. Box 872111 Mail Code: 8809
Tempe, Arizona 85287-2111

You replied to this message on 7/10/2012 10:03 AM.

From: John Keller <jkeller@fsu.edu>
To: 'Angela Barrus'
Cc:
Subject: RE: Requesting Permission to Use the ARCS Motivation Survey Instrument

Dear Angela,

Thank you for your informative and interesting message about your research! Certainly, you are welcome to use the IMMS in your research.

If you would like to have electronic copies of any of my publications, or articles about volition which is not as popular in the USA as writings about self-regulation, just let me know.

Best wishes for an enjoyable and successful project,
John

John M. Keller, Ph.D.
Professor Emeritus
Educational Psychology and Learning Systems
Florida State University

9705 Waters Meet Drive
Tallahassee, FL 32312-3746
Phone: 850-294-3908

Official ARCS Model Website: http://arcsmodel.com
Professional Website: http://mailer.fsu.edu/~jkeller/JohnsHome/

Keller, J.M. (2010), ***Motivational Design for Learning and Performance: The ARCS Model Approach***. New York: Springer. Now available in English and Japanese. Will soon be available in Korean.

"Do not seek to follow in the footsteps
of the men of old. Seek what they sought."
Bashō (1644 – 1694)

APPENDIX C

INSTRUMENTS

Classroom Observation Instrument (Teach 21, 2012)

Teacher: Period: Number of Students: Day of Week:

Lesson Title ____

1. Physical Setting/Classroom Environment (Mark all that apply.)

A. Classroom Facility

- ☐ Classroom adequate size for student number
- ☐ Adequate storage for resources/materials/equipment
- ☐ Furnishings allow for inquiry-based instruction
- ☐ Student Seating ____ rows ____ pairs _____ small groups ____ other _______________
- ☐ Room size will accommodate activities
- ☐ Flat top surfaces are sufficient for investigations, projects, displays, etc.

B. Classroom Environment

- ☐ Math manipulative/tools evident
- ☐ Math displays/posters promote learning
- ☐ Core curriculum materials evident
- ☐ Math student work displayed
- ☐ Adequate resources available for hands-on lesson (as appropriate)

C. 21st Century Tools

- ☐ Class set of calculators available - type __________________________
- ☐ Interactive Whiteboard
- ☐ Number of computers available to students ____ teacher ____
- ☐ Projection system
- ☐ Document camera

2. Lesson Effectiveness (Mark all that apply.)

A. Major Instructional Resources Used

☐ Textbook	☐ Manipulatives	☐ Computer to access Internet
☐ Other print materials	☐ Calculators	☐ Computer to collect/analyze data
☐ Overhead	☐ Overhead Calculator	☐ Computer to practice a skill
☐ CD/DVD	☐ 21st Century Tools	☐ Math tools (rulers, compass, protractor, etc.)

- ☐ Document Camera ☐ TI-Navigator ☐ Palms
- ☐ GPS ☐ Software like Sketchpad, Tinkperplots, or Fathom

B. Content Focus

- ☐ Number/computation
- ☐ Algebra/pre-calculus/calculus
- ☐ Geometry
- ☐ Measurement
- ☐ Data/Probability

C. Content Delivery

- ☐ Instructional resources used appropriately and effectively
- ☐ Content presented is accurate
- ☐ Use of real world context
- ☐ Focus on problem solving
- ☐ Students solved one or more non-routine, or open-ended problems

D. Inquiry-Based Lesson Design

- ☐ Launch
- ☐ Investigation
- ☐ Summary/Closure

E. Grouping Arrangement(s) Used

- ☐ Whole Group
- ☐ Small groups working on same task
- ☐ Small groups working on different tasks
- ☐ Individuals working on same task
- ☐ Individuals working on different tasks
- ☐ Grouping arrangements were appropriate for the instructional goal and activity ☐

F. Teacher and Student Behaviors Observed

Teacher Behaviors

- ☐ Setting up and guiding students through meaningful real-world problems
- ☐ Moving around the room monitoring/questioning
- ☐ Encouraging students to consider multiple ways to solve problems/test solutions
- ☐ Guiding students in the use of manipulatives/technology
- ☐ Promoting student use of inquiry/creativity through questioning/collaboration
- ☐ Facilitating discussions about problem-solving processes/ efficiency/effectiveness
- ☐ Leading students through discussions/journaling of their understanding

Student Behaviors

- ☐ Interacting with others
- ☐ Working alone

- Working in groups to test solutions
- Working in teams to challenge and defend solutions
- Applying math to real world problems

21st Century Information and Communication Skills

- Sharing solution processes and listening to others share their thinking
- Defending solution processes' efficiency and usefulness
- Communicating math ideas: demonstrations, models, drawings, and arguments
- Helping to clarify each other's learning through discussion/modeling

G. Instructional Strategies

- Connection to prior knowledge
- Provides differentiated instruction
- Teacher modeling
- Collaborative grouping
- Opportunities for students to justify solutions
- Incorporate varied assessments

3. Questioning Strategies (Mark all that apply.)

- Wait Time I Wait Time II No/limited wait time
- Questions were higher-order and stimulated broad student responses
- Questions were lower-cognitive and stimulated narrow student responses
- No questions were asked by the teacher or posed through the activity being conducted
- Teacher used strategy to ensure all students had opportunity to respond
- Teacher asked probing follow-up questions based on students' understanding (individuals, small group, whole class)
- Students are encouraged to ask questions of each other and of the teacher
- Teacher provided specific praise
- Teacher provided general praise
- Teacher provided no praise
- The questioning strategies checked for student understanding of apparent instructional goal Yes No

4. Classroom Climate

A. Student Involvement

- Majority of students demonstrated interest/were engaged and on task
- Most students take initiative in classroom discussions
- Majority of students uninterested or apathetic
- Majority of students were frequently off task

B. Classroom Management

- Classroom orderly, no disruptions that impaired learning environment
- Classroom generally orderly, but some disruptions impaired learning environment
- Classroom disorderly, frequent student disruptions seriously impaired the learning

environment
- ☐ The climate was generally positive
- ☐ The climate enhanced learning opportunities for students

5. Development of Higher Order Thinking Skills

A. Check all skills that were introduced and/or developed in the observed lesson.

- ☐ Making observations
- ☐ Reciting/recalling facts
- ☐ Classifying
- ☐ Estimating
- ☐ Choosing appropriate strategies
- ☐ Measuring
- ☐ Collecting/recording data
- ☐ Comparing/contrasting
- ☐ Organizing and displaying data
- ☐ Drawing conclusions
- ☐ Interpreting and analyzing data
- ☐ Making predictions
- ☐ Selecting problem-solving strategy
- ☐ Creating/formulating patterns/equations
- ☐ Justifying/verifying solutions/strategies

B. Learner Attitudes Demonstrated

- ☐ Dependent on others
- ☐ Cooperation
- ☐ Persistence
- ☐ Responsibility
- ☐ Confidence
- ☐ Enthusiasm
- ☐ Objectivity
- ☐ Accuracy
- ☐ Critical thinking
- ☐ Self-directed
- ☐ Curiosity

C. Student ARCS Model Alignment (Only checked and rated if observed)

☐ Attention
1 2 3 4 5

☐ Relevance
1 2 3 4 5

☐ Confidence
1 2 3 4 5

☐ Satisfaction
1 2 3 4 5

Adapted from instructional support materials made available at
http://wvde.state.wv.us/teach21 downloaded September 15, 2012

Keller, John (2010). Motivational Design for Learning Performance. The ARCS Model Approach. Springer, Boston.

Learning and Study Strategies Inventory (LASSI) for High School Students Scale Descriptions and Sample Items (Weinstein & Palmer, 1990)

The LASSI inventory includes ten subscales. The scales listed below are those that this study focused on analyzing as they aligned best to the principles in the ARCS motivation instructional design model.

SRL Subscales Analyzed in this Study

1. **Attitude** — Interest in education and school. Is school and the goals associated with it important to them?

   Sample Items:
   I feel confused and undecided as to what my educational goals should be.
   I only study the subjects I like.

2. **Self-Testing** — items focus on reviewing and preparing for classes and tests. Most of the items deal with some aspect of comprehension monitoring.

   Sample Items: I have difficulty adapting my studying to different types of subjects.
   In taking tests, writing themes, and other schoolwork, I find I have not understood what the teacher wants and lose points because of it.

3. **Motivation** — addresses students' diligence, self-discipline, and willingness to work hard. Do students easily lose interest in their classes? Do they try to stay up-to-date with their classes?

   Sample Items:
   When work is difficult I either give up or study only the easy parts.
   I set high standards or goals for myself in school.

4. **Information Processing** — Using mental imagery, verbal elaboration, comprehension monitoring, and reasoning. Can students create images to aid their memory? Can they reason from hypotheses to form conclusions?

   Sample Items:
   I have a hard time finding the important points in my reading.
   Often when studying I seem to get lost in details and can't remember the main ideas.

ARCS IMMS Survey Sample Items and Scale Descriptions (Keller, 2010)

Scoring: Not true – 1; Slightly true – 2; Moderately true – 3; Mostly true – 4; Very true –5

1. When I first looked at this course, I had the impression that it would be easy for me.
2. There was something interesting at the beginning of the course that got my attention.
3. This material may be more difficult to understand than I would like for it to be.
4. After completing the online tutorial, I feel confident that I know what I was supposed to learn from this course.
5. Completing the learning materials in this course will give me a satisfying feeling of accomplishment.
6. It is clear to me how the content of this material is related to things I already know.
7. Many of the modules had so much information that it was hard to pick out and remember the important points.
8. These learning materials are eye-catching.
9. There were stories, pictures, or examples that showed me how this topic could be important to some people.
10. Completing this course successfully was important to me.

Attention

We want the learning materials to capture and maintain your attention.

Relevance

We want the material covered in the course to be useful and relevant to you personally and in your academic life.

Confidence

We want all students to successfully complete this course.

Satisfaction

We want you to be satisfied with the course and your performance in it.

Acuity Algebra (Achievement Measure) Sample Items (McGraw Hill Acuity Algebra)

- If a number is divided by 4, and then 3is subtracted, the result is 0. What is the number?
- What is the value of the expression $2x^2 + 3xy – 4y^2$ when $x = 2$ and $y = - 4$?
- If A represents the number of apples purchased at 15 cents each and B represents the number of bananas purchased at 10 cents each, what is the total value of the purchases?
- $16x - 8 =$

Accuplacer Reading Comprehension Placement Test Sample Items (Accuplacer.org)

Read the statement or passage and then choose the best answer to the question. Answer the question based on what is stated or implied in the statement or passage.

In the words of Thomas DeQuincey, “It is notorious that the memory strengthens as you lay burdens upon it.” If, like most people, you have trouble recalling the names of those you have just met, try this: The next time you are introduced, plan to remember the names. Say to yourself I’ll listen carefully; I’ll repeat each person’s name to be sure I’ve got it, and I will remember. You’ll discover how effective this technique is and probably recall those names for the rest of your life.

The main idea of the paragraph maintains that the memory
A. always operates at peak efficiency.
B. breaks down under great strain.
C. improves if it is used often.
D. becomes unreliable if it tires.

It is said that a smile is universally understood. And nothing triggers a smile more universally that the taste of sugar. Nearly everyone loves sugar. Infant studies indicate that humans are born with an innate love of sweets. Based on statistics, a lot of people in Great Britain must be smiling because on average, every man, woman and child in that country consumes 95 pounds of sugar each year.

This passage implies that the writer thinks that 95 pounds of sugar per person per year is
A. a surprisingly large amount
B. a surprisingly small amount
C. about what one would expect
D. an unhealthy amount

10. The wheel has been used by humans since nearly the beginning of civilization and is considered one of the most important mechanical inventions of all time. Most primitive technologies since the invention of the wheel have been based on its principles, and since the industrial revolution, the wheel has been a basic element of nearly every machine constructed by humankind. No one knows the exact time and place of the invention of the wheel, but its beginnings can be seen across many ancient civilizations.

According to this passage, the wheel is an important invention because
a. it is one of the world’s oldest inventions
b. it forms the basis of so many later inventions
c. it is an invention that can be traced to many cultures
d. it is one the world’s most famous inventions

Learning Connections Inventory HS Version Sample Items

(Dawkins, Kottkamp, & Johnston, 2010)

Scoring: Never Ever – 1; Almost Never – 2; Sometimes – 3; Almost Always – 4; Always –5

1. I would rather build a project than read or write about a subject.
2. I need clear directions that tell me what the teacher expects before I begin.
3. I generate lots of unique or creative ideas.
4. I memorize lots of facts and details when I study for a test.
5. I feel better about an assignment when I double check my answers.